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EDDY CURRENT SCANNING REPORT

FNAL-3RDHARMONIC CAVITIES #3-6

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1 INTRODUCTION

As part of Fermilab's effort to develop 3rd harmonic cavities, the niobium blanks as delivered by Wah-Chang were scanned with the eddy-current technique to reveal foreign inclusions or other sub-surface defects. The results of the scanning procedure are reported in this note. Also included are the results of a simple visual inspection of the surface. The report discusses some of the defects detected and concludes with recommendations regarding the use of the blanks for the subsequent cavity fabrication.

Fermilab recently commissioned and upgraded a scanner (Figure 1), on loan from SNS. A recent cross-calibration campaign with DESY revealed that, after filtering with a custom-made Filter program Fionda[1], this scanner is capable of the sensitivity and resolution of the DESY scanner[2].

To accommodate the smaller samples for the Fermilab 3.9 GHz cavities a special sample-holder[3] had to be fabricated (see Figure 1). The SNS cavities were fabricated from much larger Nb sheets.

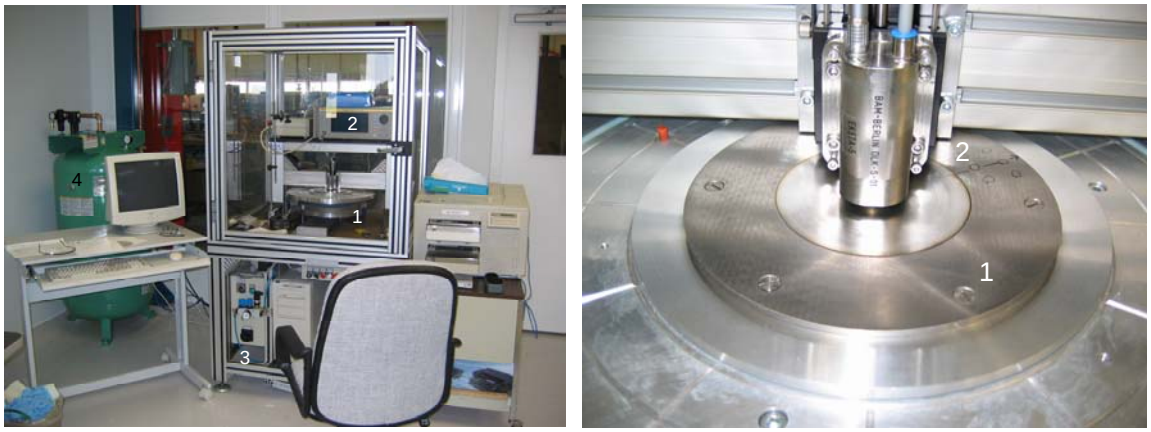


Figure 1: Left: SNS eddy current scanner at Fermilab. 1) turn-table with sample, 2) eddy-current tester, 3) main panel, 4) compressed air receiver. Right: sample-holder with sample and eddy-current probe.

[1] C. Boffo, "FIONDA (Filtering Images Of Niobium Disks Application) Filter Application for Eddy Current Scanner Data Analysis", Fermilab Technical Memo – TM-2313-TD, 05/16/05.
[2] P. Bauer et al., "Calibration of the SNS Eddy Current Scanner for the Quality Control of the Niobium Blanks for Fermilab's SRF Cavities", Fermilab Technical Division Internal Note TD-05-016, 02/23/05.
[3] P. Bauer et al., "Eddy Current Scanner Operating Instructions", Fermilab Technical Division Internal Note TD-04-029, 08/04

The following scanning procedure was applied to each sample.

1) The system was switched on at least one hour before testing. Disc 22_2[4] was run first to determine whether the scanner is operating correctly.
2) The sample was inspected under the magnifying glass and any observations concerning the condition of the surface (scratches, etch-pits, de-colorations, …etc) were noted. Samples were always handled with gloves.
4) After mounting the sample the probe was moved over the center of the sample and brought down (the turn-table was de-activated). The probe was then moved up or down using the micro-slide to determine the maximum height at which electrical continuity between sample-holder and probe-holder existed. Then the probe was backed up slightly (~5 microns) from this position.
5) The phase was set such as de-couple defects (y-signal) from disc thickness variations (x-signal) and sometimes the amplifier gains were varied as well as the low-pass filter settings.
6) The measurement was launched, with the files named according to the following convention: 3harmb1_disc#_disc-side_run#). Typically only one run was performed for each side of each sample.
7) The measurement was continuously observed and the probe pulled up with the micro-slide whenever touching between the sample and probe occurred (these measurements were then repeated with the new height setting.
8) The measurement result was saved, printed and inspected. In many cases several measurements were performed per disc.
9) The results were run through the filter software Fionda for further improvement of the defect detection sensitivity.

Figure 2 shows several scans of the calibration disc (b1-22/2) obtained before and after the scanning campaign reported here. Also shown is a scan of a similar disc performed by DESY.

[4] 3rd harmonic – batch 1 – disc 22- side 2 is the disc shows several strong signals in the DESY and FNAL scans and is therefore used as reference.

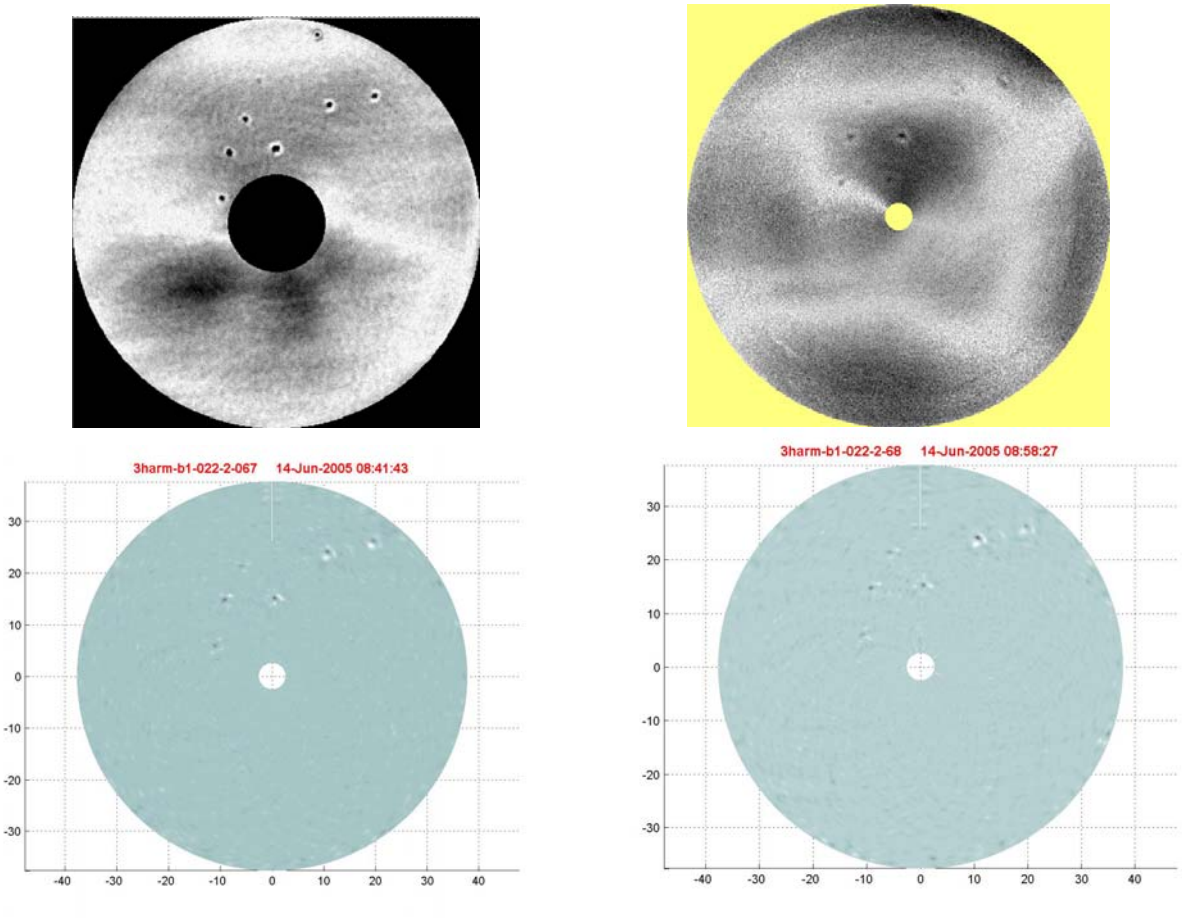


Figure 2: Example of eddy current scans performed on a niobium disc for Fermilab's 3rd harmonic cavity with the DESY scanner (top left) and SNS/FNAL scanner (top right and left & right bottom). The bottom two scans were obtained after the measurement campaign reported here, the one on top right, before.

The typical scanner settings for the scans are summarized in Table 1. The data shown in the following chapters are all of channel 1 (y-signal). The results obtained with the high frequency (1.2 MHz) channel (2) are not understood to this date and the results are therefore not discussed further here.

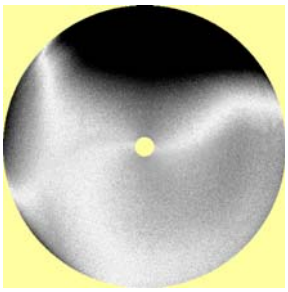
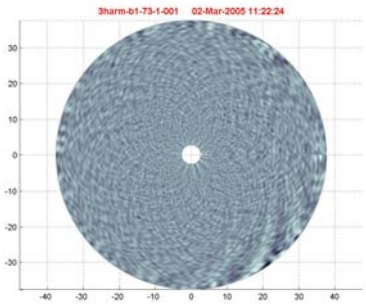
Special measurements were performed in some cases to investigate further the observed defects. These measurements are reported in a special section at the end of this report.

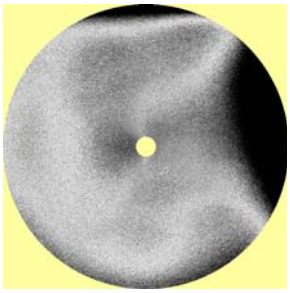
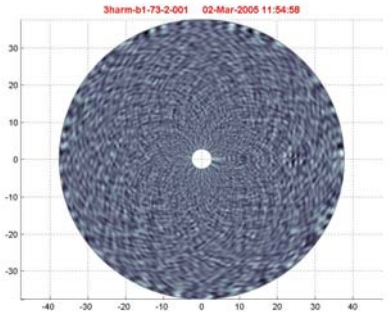
Table 1: Main menu settings of the Rohmann ELOTEST. *In some instances a pre-amplifier gain of 30 was used.

Parameter	Channel 1 – SNS/FNAL
Frequency	190 kHz
Probe Adjust	50 Ohm
Probe Current	333 mA
Phase	205 deg
Pre-amplifier	30 dB
Total gain (x/y)	46/66dB
X/Y spread	0/20 dB
Highpass filter	static
Lowpass filter	0.5-2 kHz
BW limit	off
Track spacing	50 μm
Point spacing	0.225°
Turntable speed	105 rpm

2 SCANNING RESULTS

The following shows the scans obtained on discs 73-162 after filtering with Fionda. Discs 73-82 were filtered with an older version of Fionda, which did not have a “calibration defect”. This calibration defect serves to normalize the color scale of the filtered scans. Therefore the scans 73-82 have a very different appearance, in the absence of any defect the available color scale is applied to a smaller signal range and thus smaller signal variations are amplified. The scans of discs 73-130 are rotated +90° with respect to the usual representation such that the reference position (0 degree, mark on disc) is at the 3:00 position rather than the 12:00 position. Typically the end-point of the EDM-cut is chosen as the reference position.

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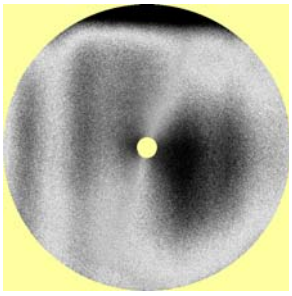
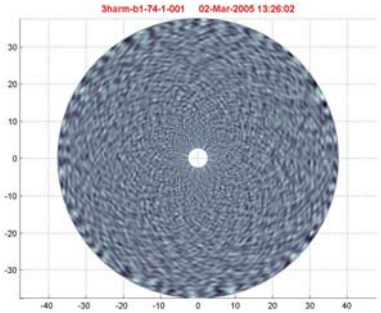

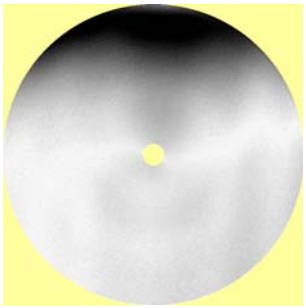
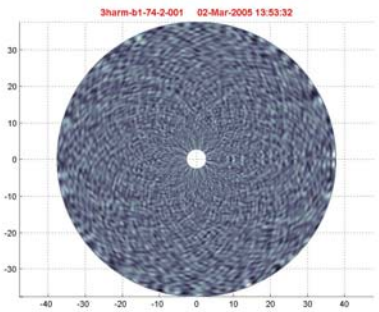

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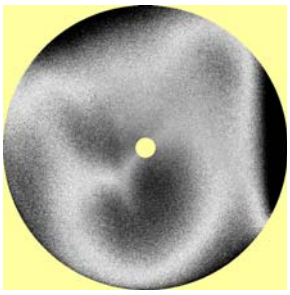
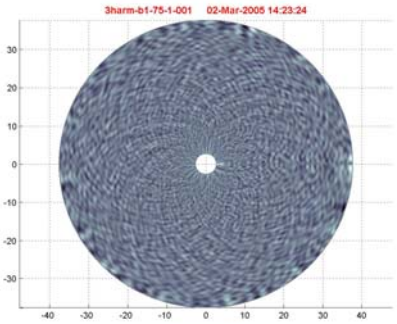

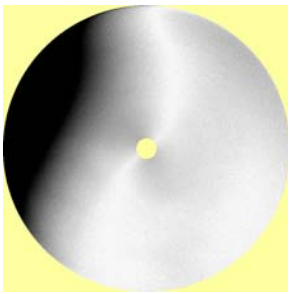
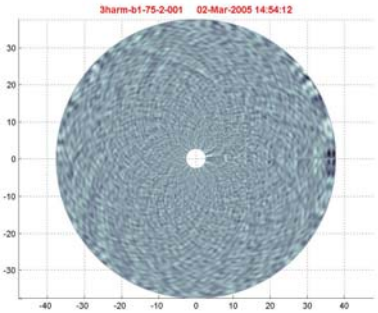

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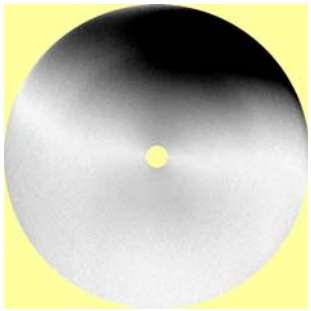
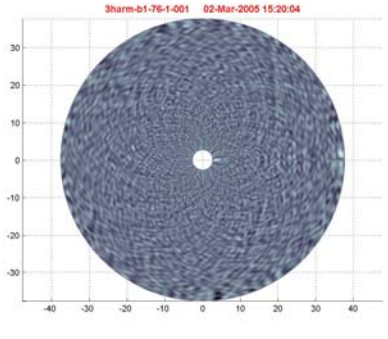

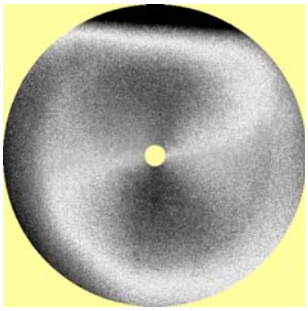
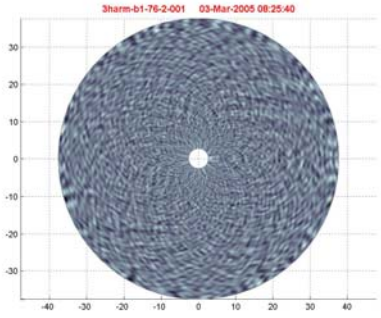

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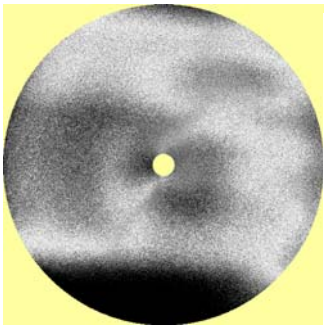
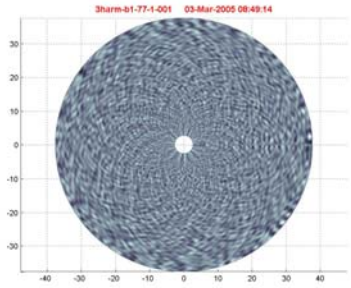

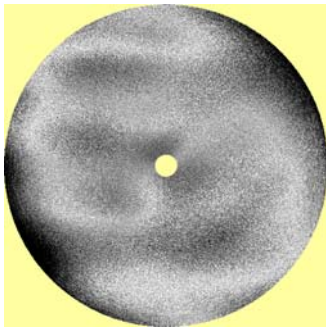
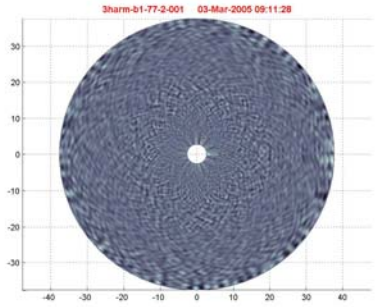

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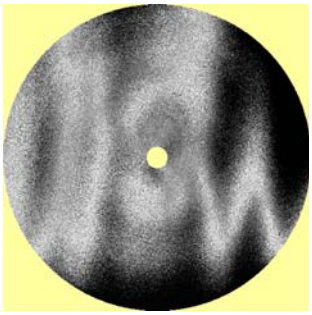
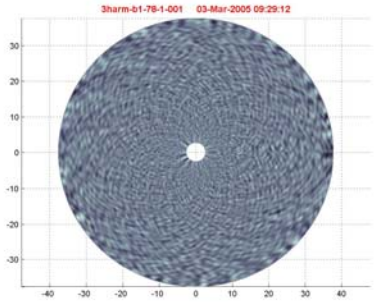

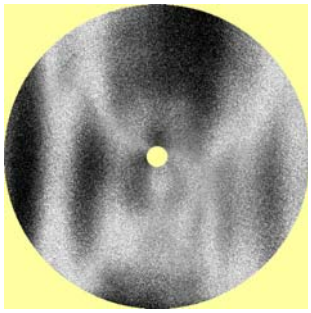
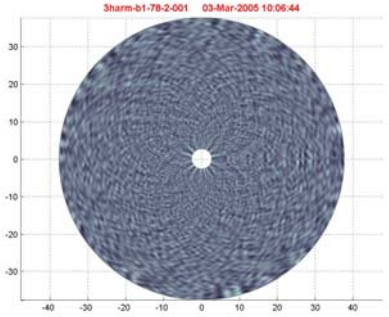

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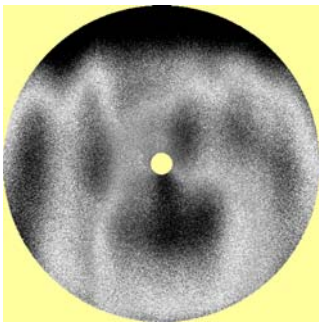
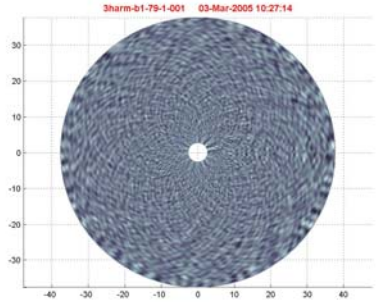

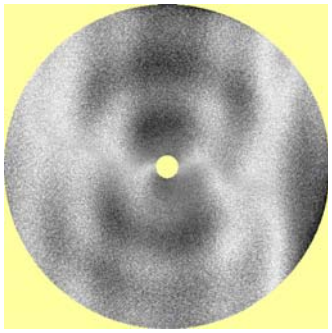
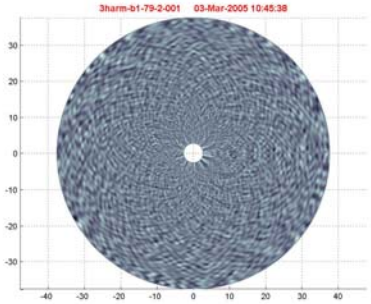

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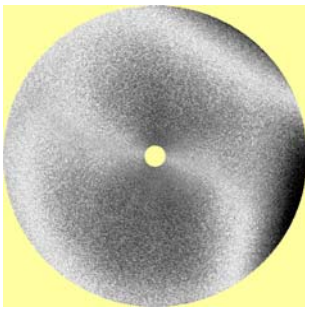
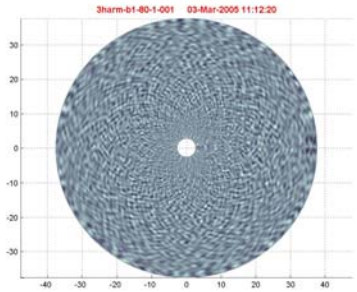

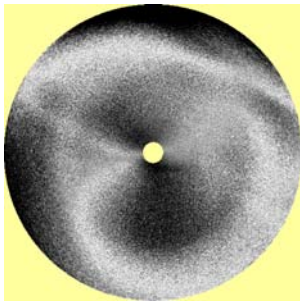
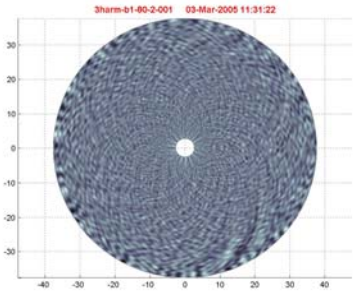

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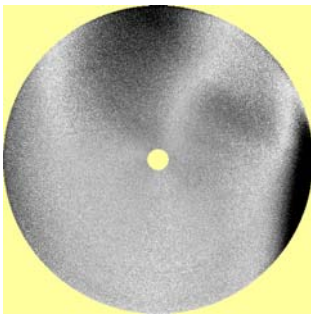
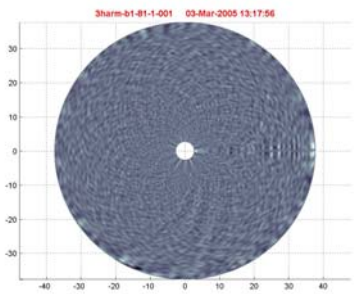

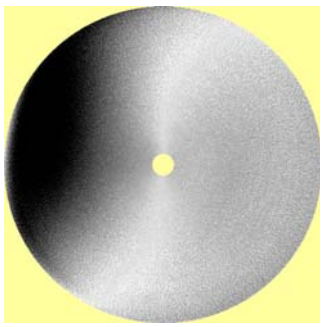
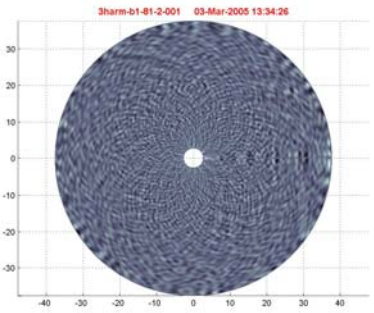

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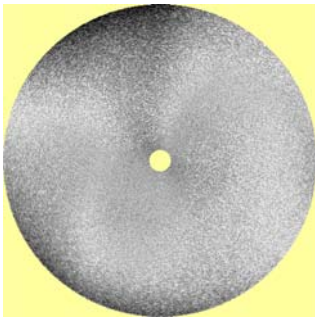
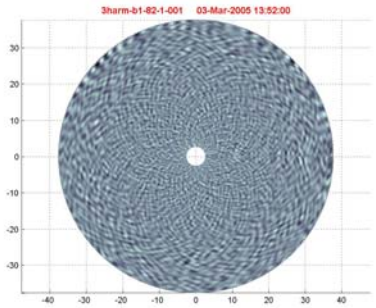

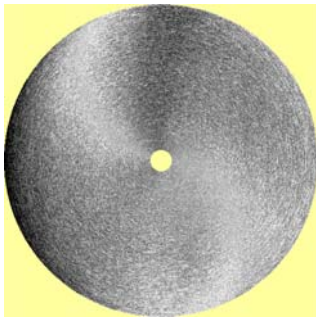
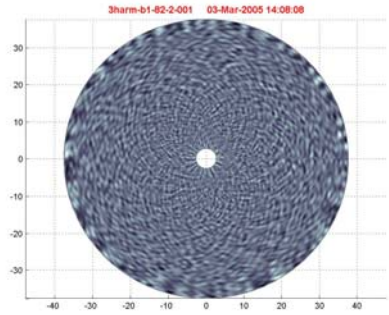

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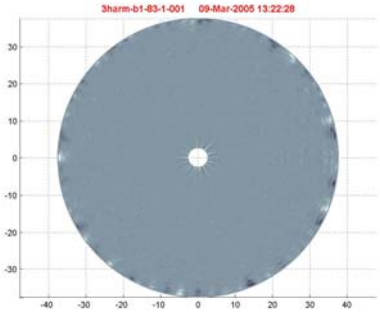


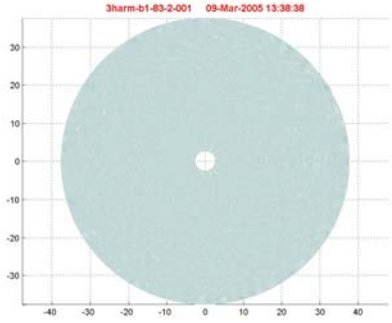

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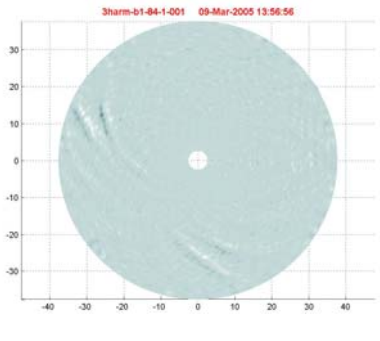

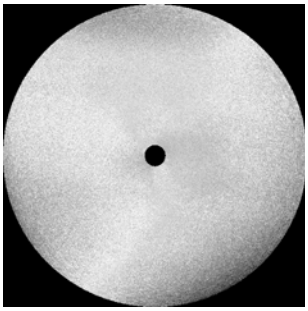
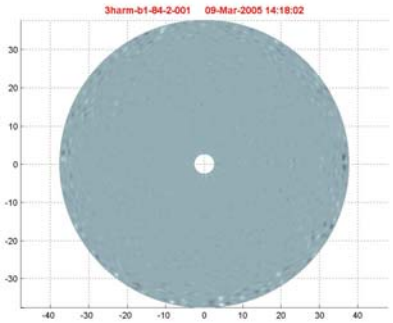

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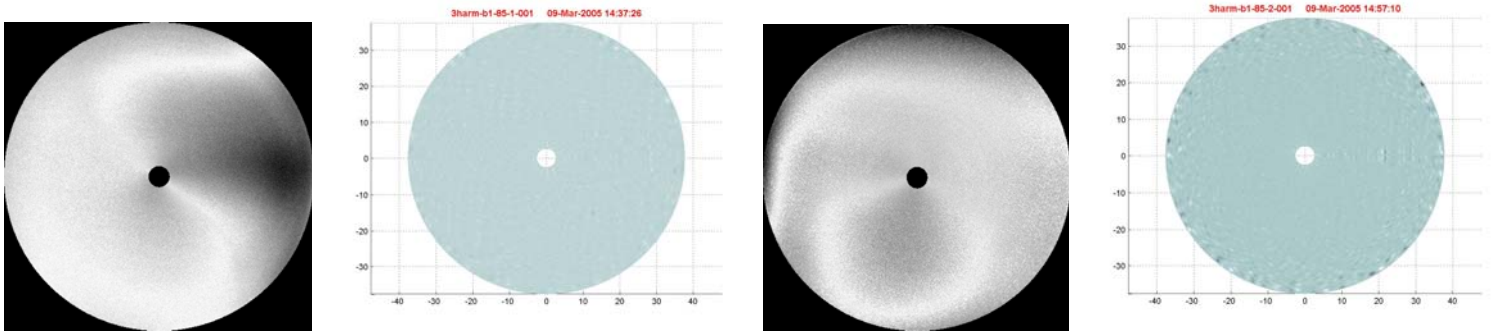

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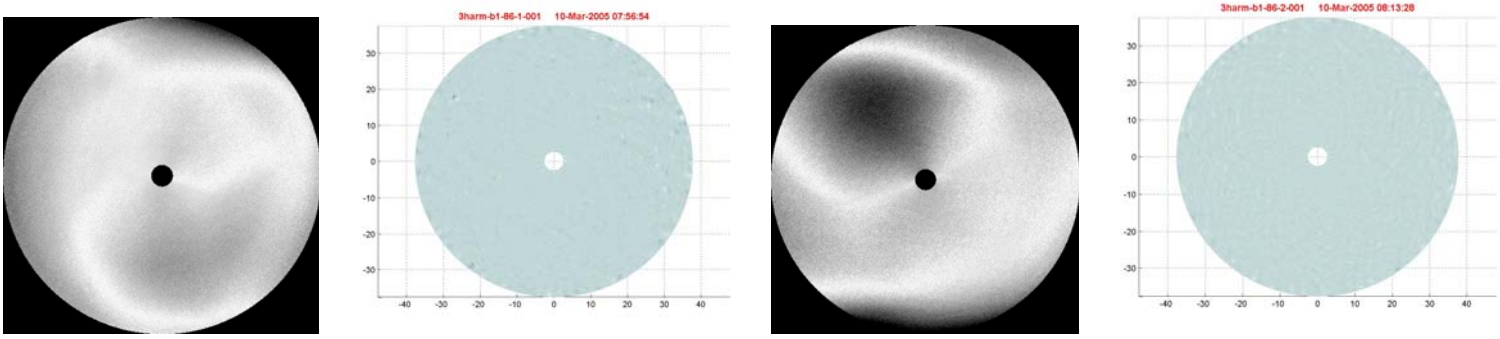

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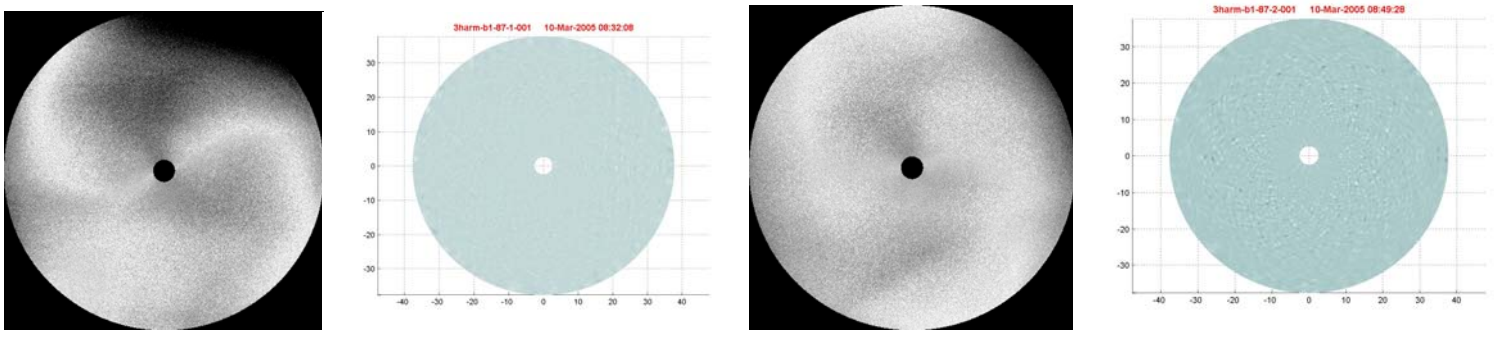
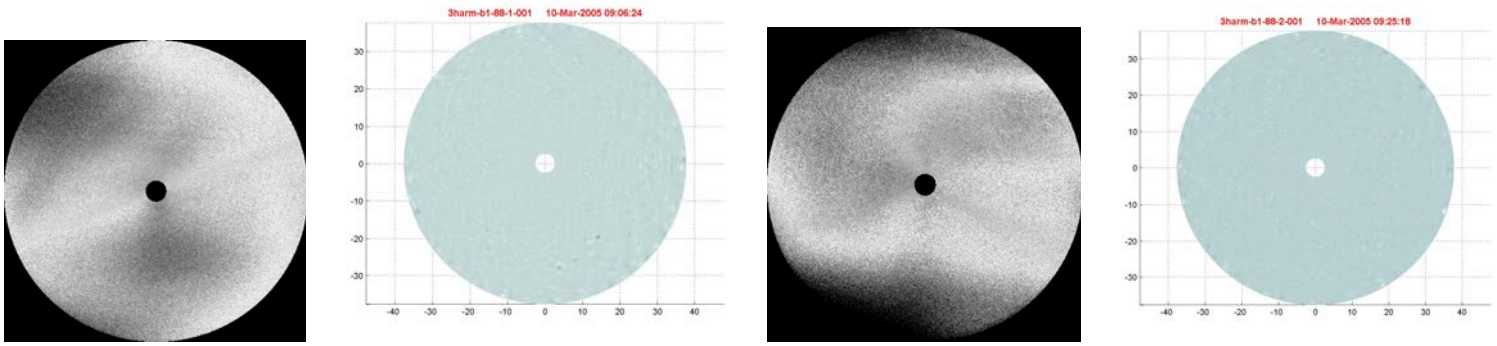
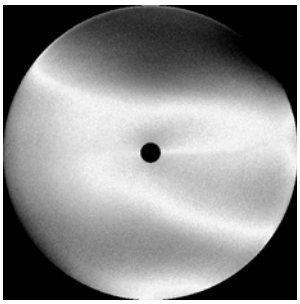
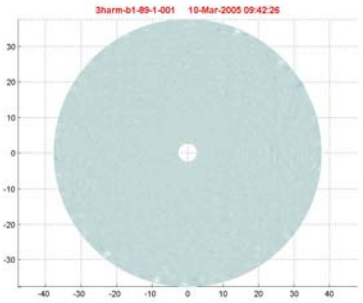
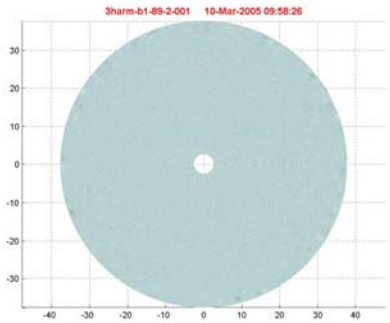


Disc 87 – side 1/2;

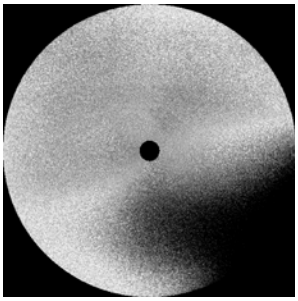
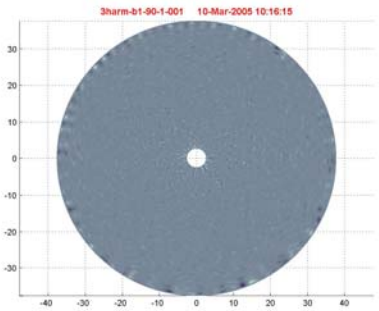


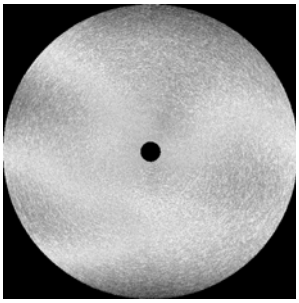
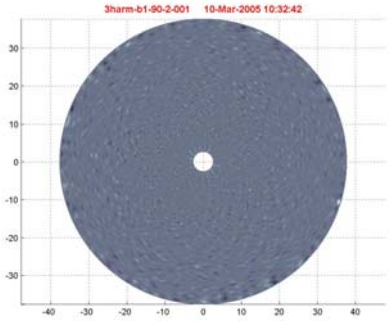
Disc 88 – side 1/2;

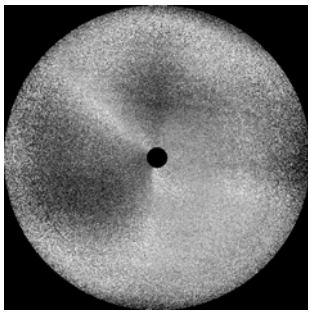
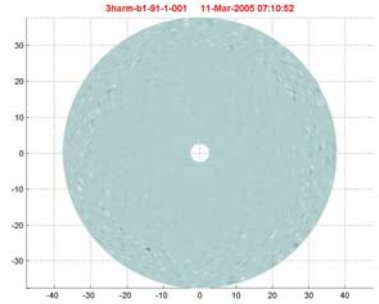



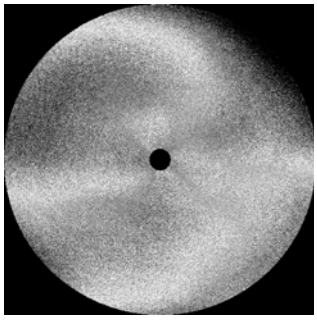
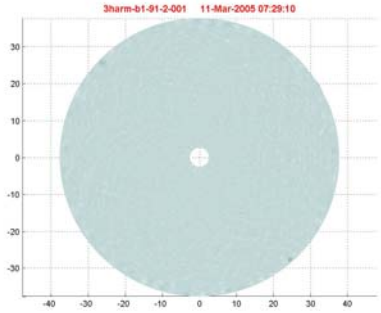
Disc 89 – side 1/2;

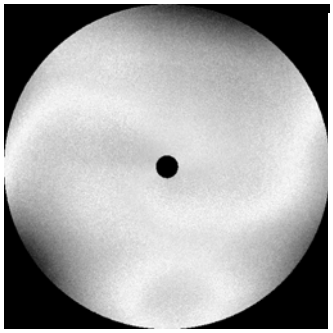
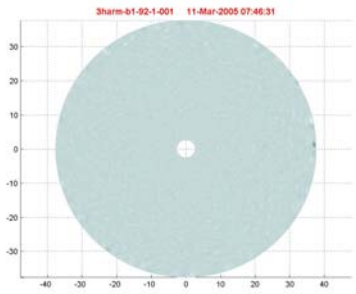



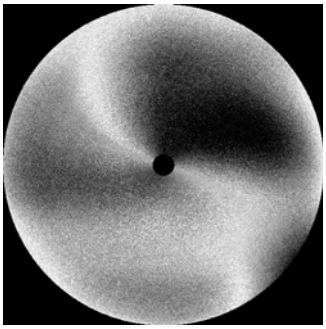
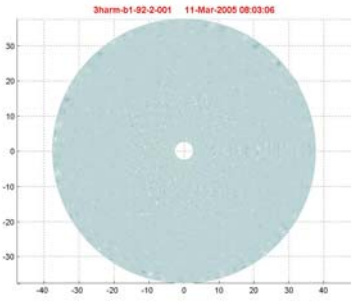
Disc 90 – side 1/2;

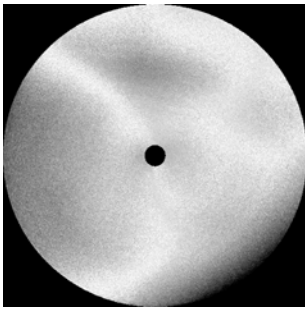
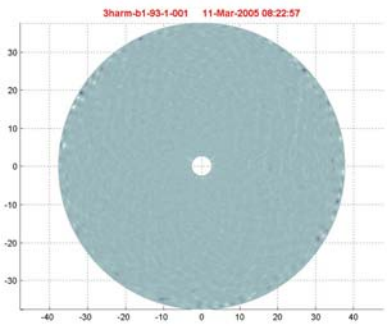



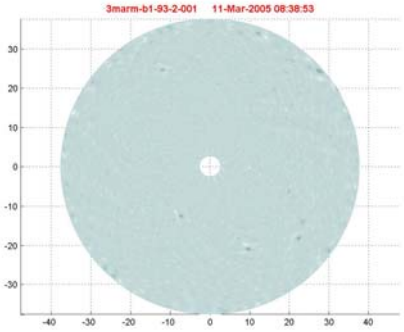
Disc 91 – side 1/2;

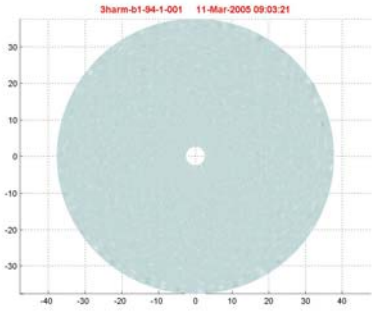



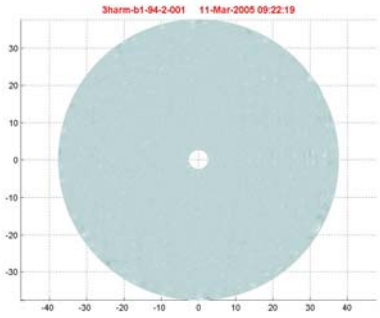
Disc 92 – side 1/2;

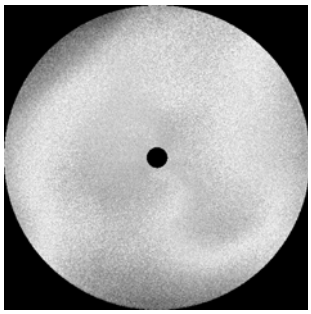
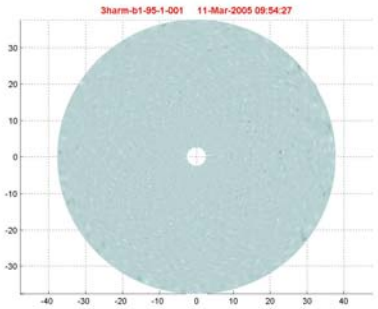


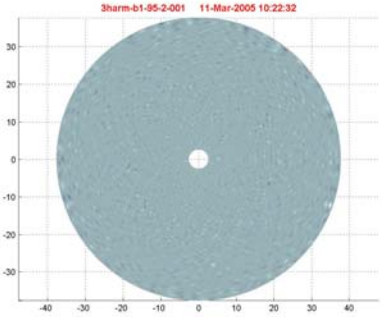
Disc 93 – side 1/2;

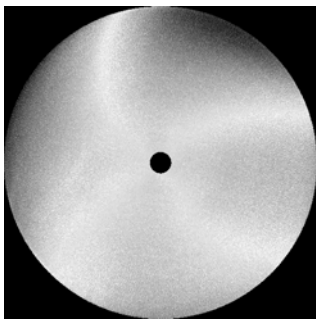
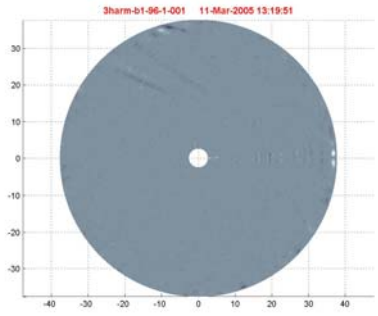



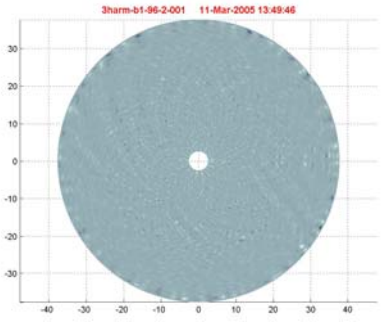
Disc 94 – side 1/2;

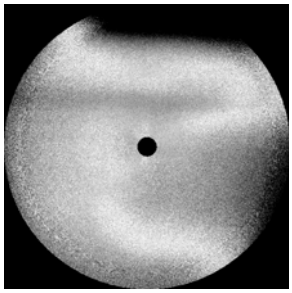
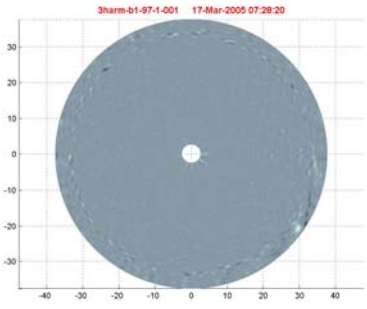



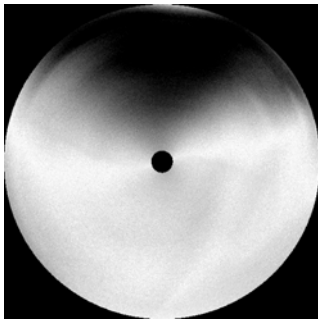
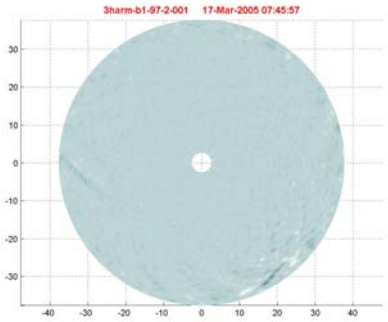
Disc 95 – side 1/2;

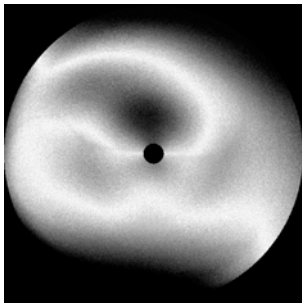
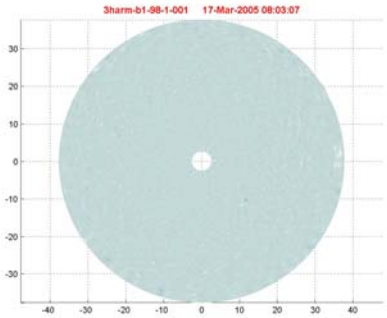



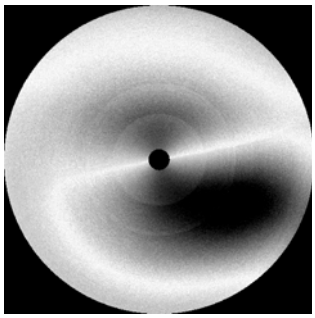
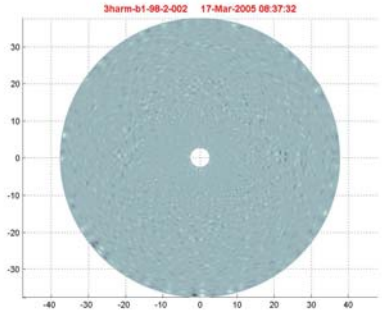
Disc 96 – side 1/2;

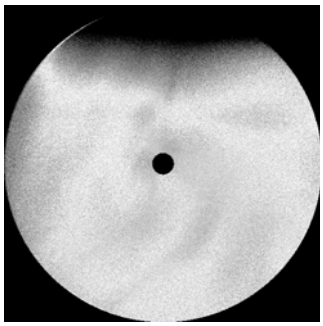
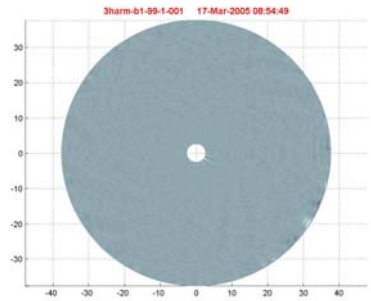



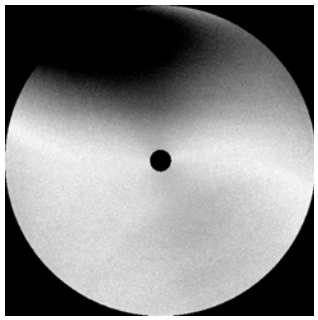
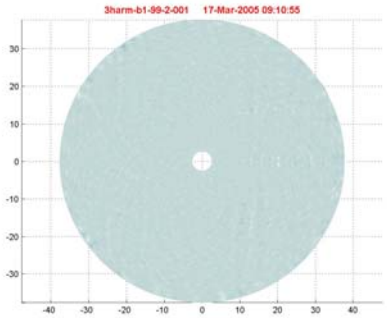
Disc 97 – side 1/2;

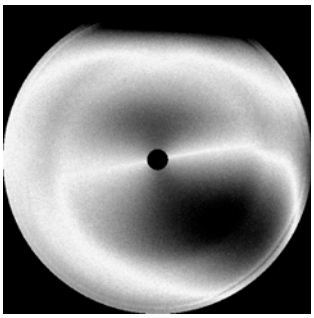
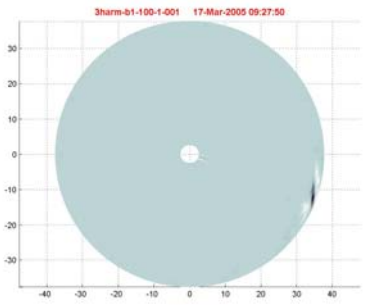



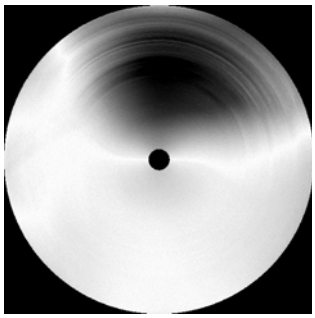
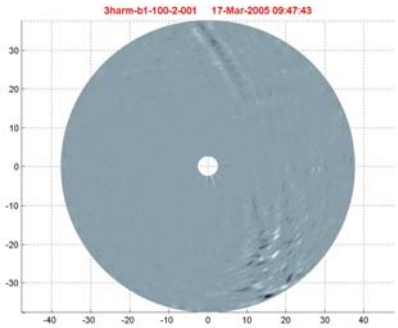
Disc 98 – side 1/2;

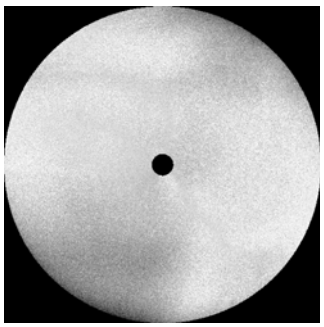
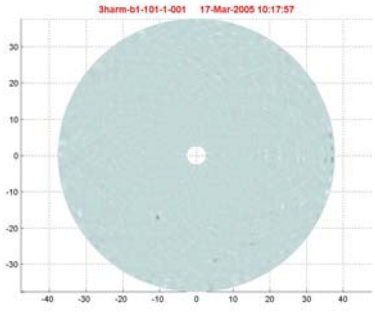



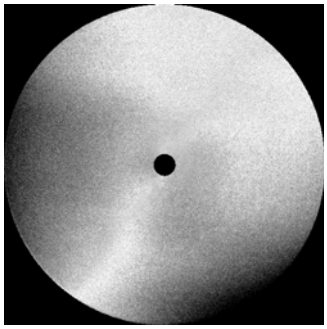
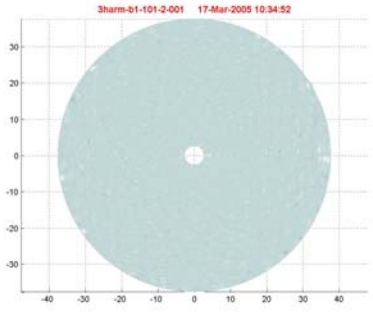
Disc 99 – side 1/2;

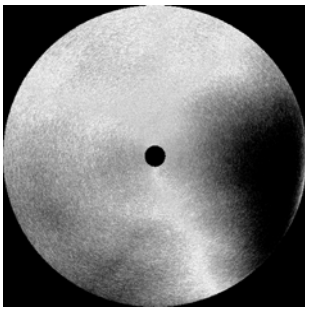
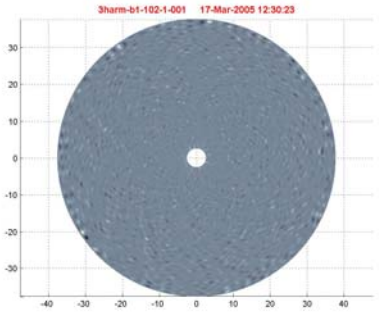



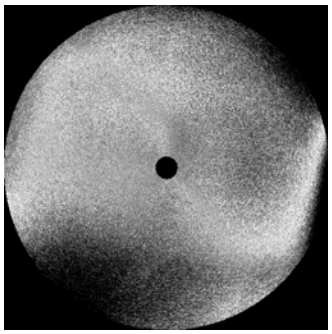
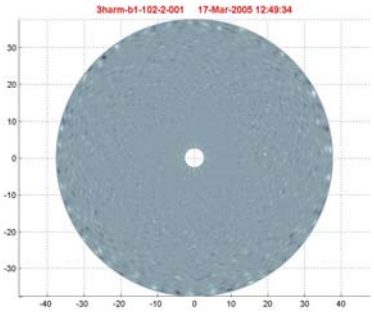
Disc 100 – side 1/2;

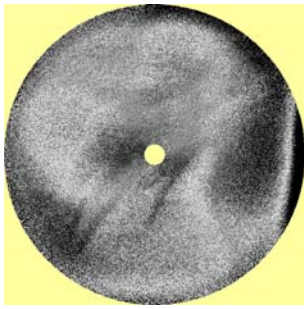
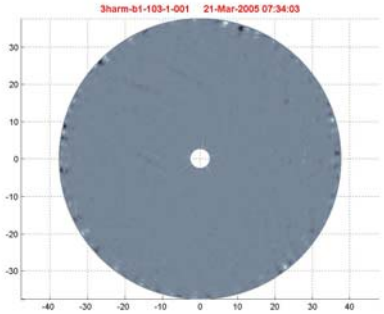



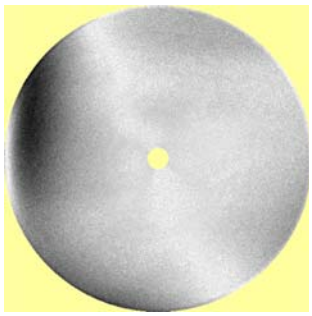
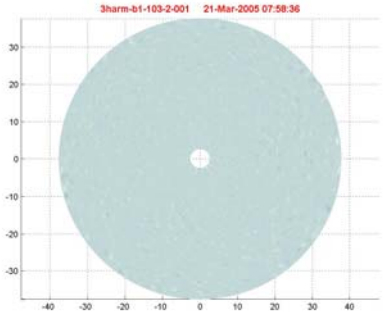
Disc 101 – side 1/2;

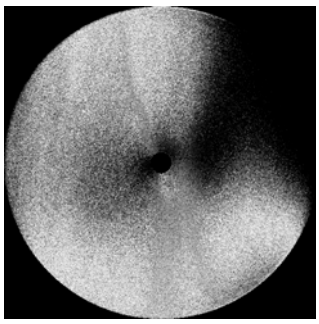
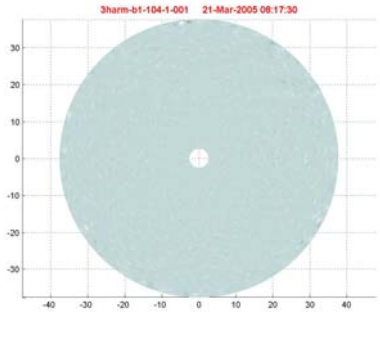



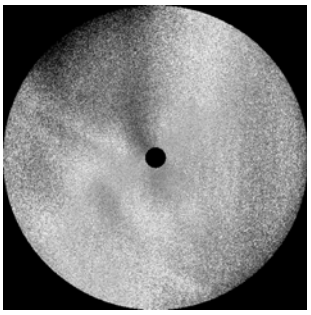
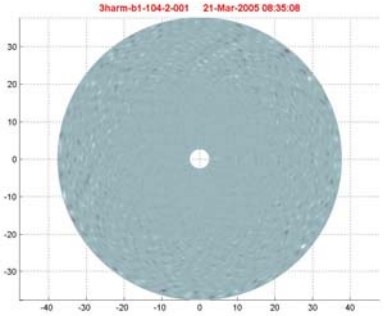
Disc 102 – side 1/2;

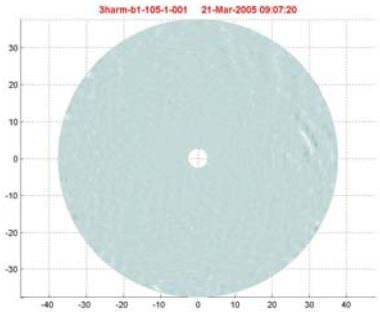



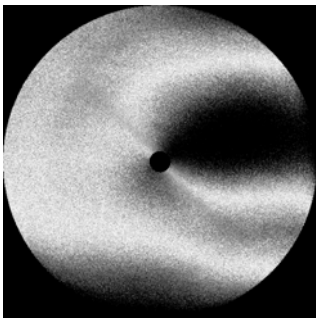
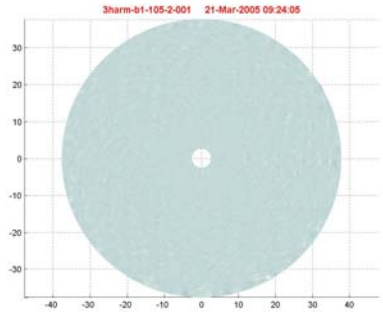
Disc 103 – side 1/2;

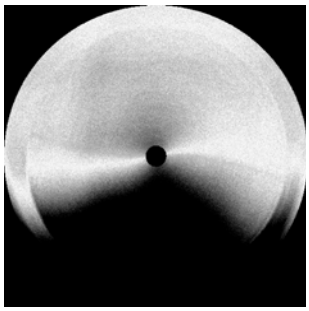
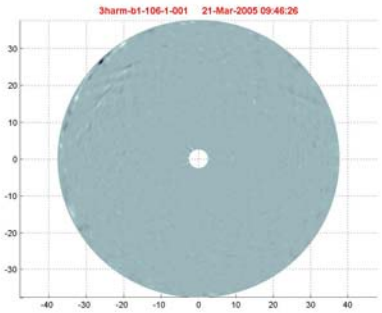



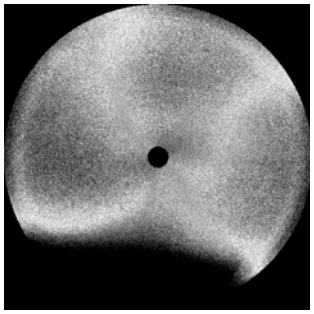
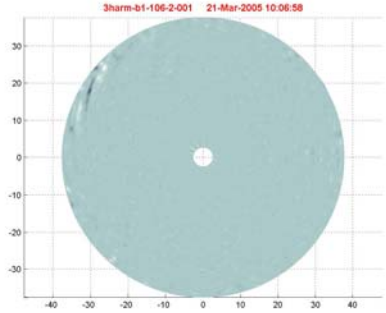
Disc 104 – side 1/2;

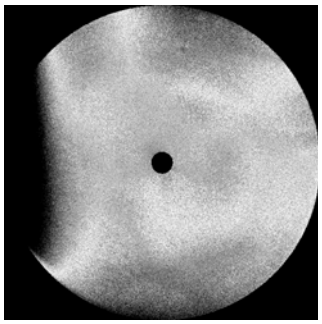
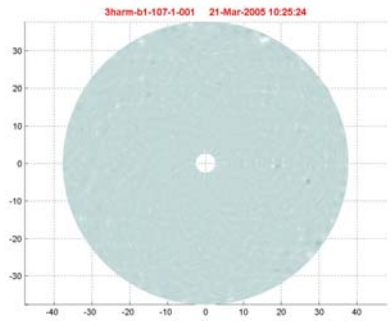



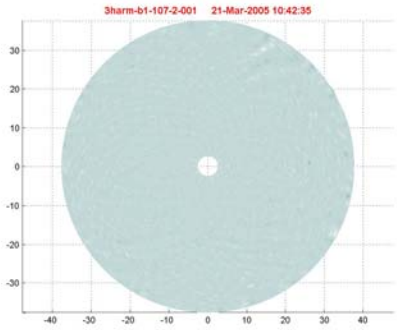
Disc 105 – side 1/2;

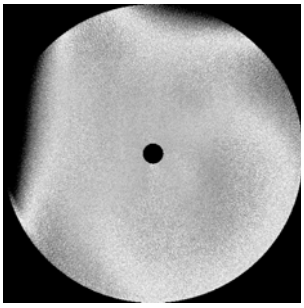
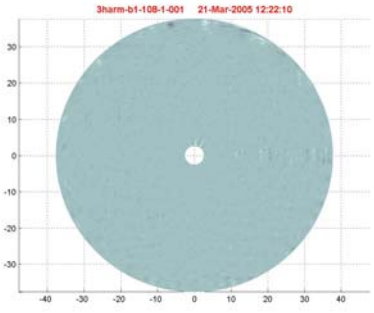



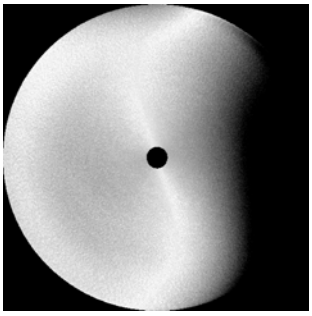
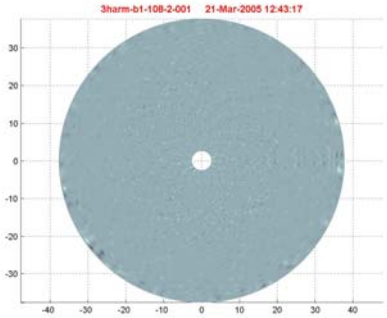
Disc 106 – side 1/2;

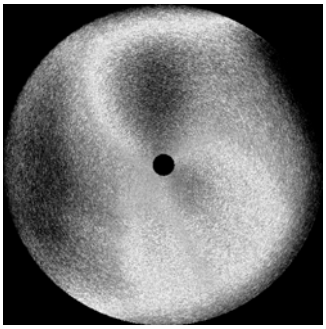
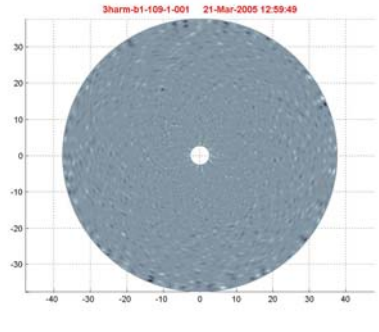


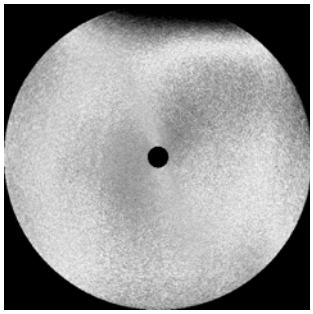
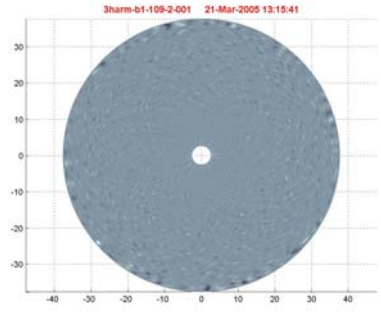
Disc 107 – side 1/2;

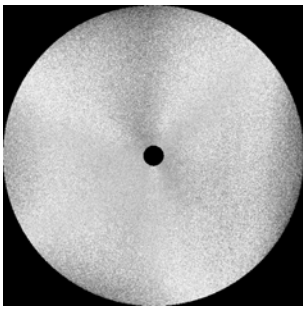
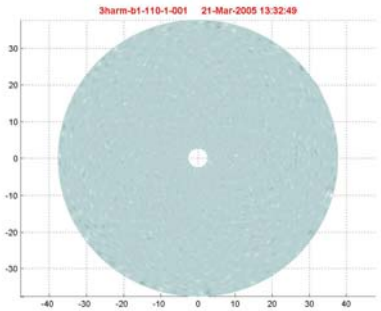



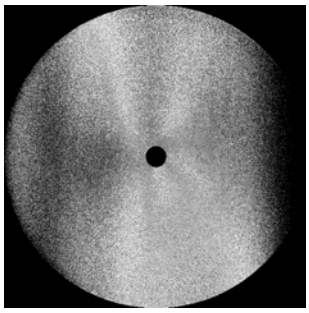
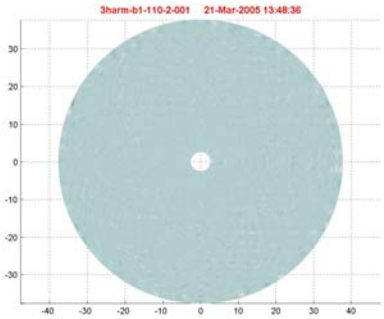
Disc 108 – side 1/2;

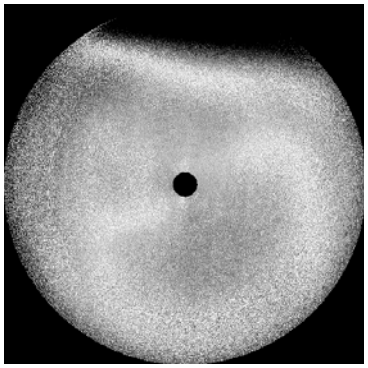
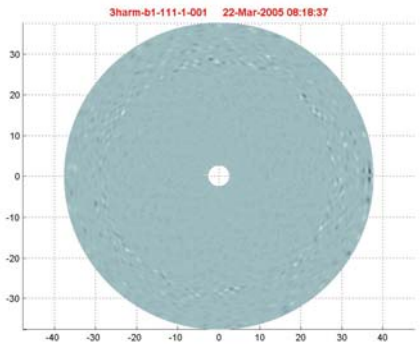



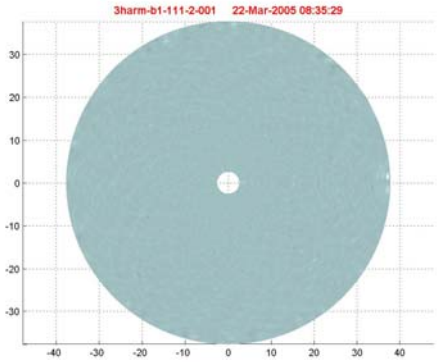
Disc 109 – side 1/2;

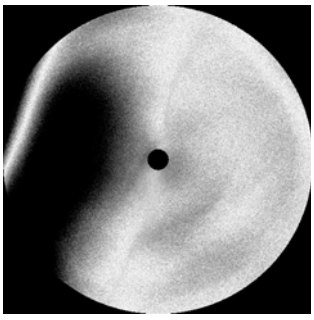
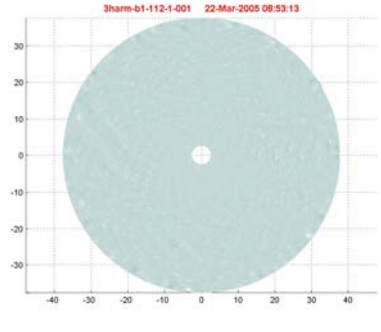



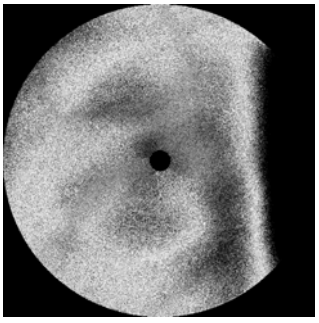
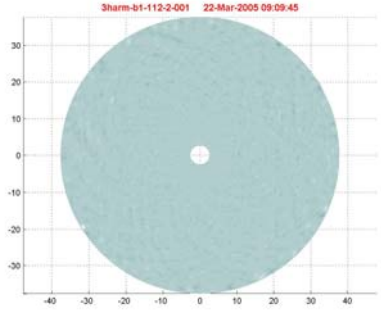
Disc 110 – side 1/2;

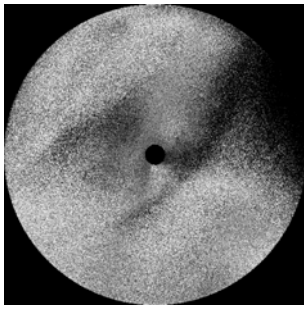
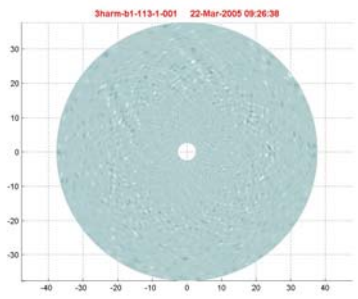


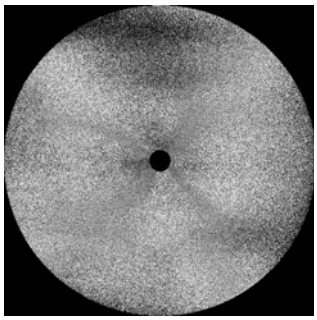
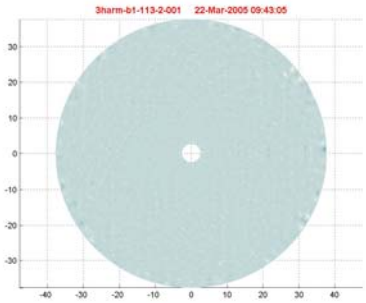
Disc 111 – side 1/2;

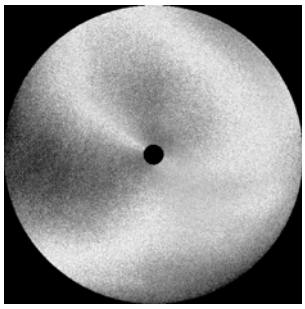
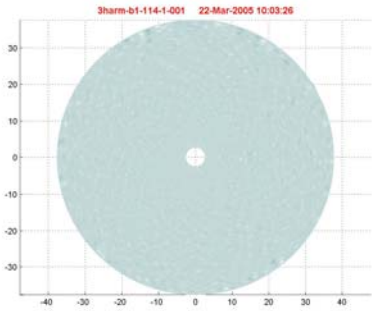



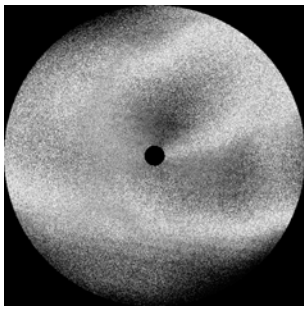
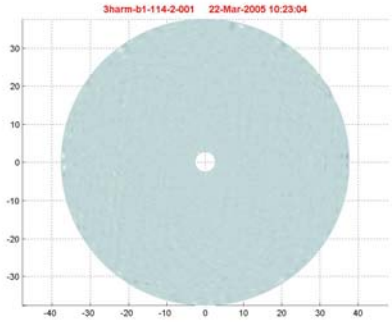
Disc 112 – side 1/2;

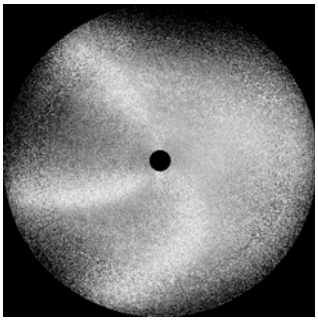
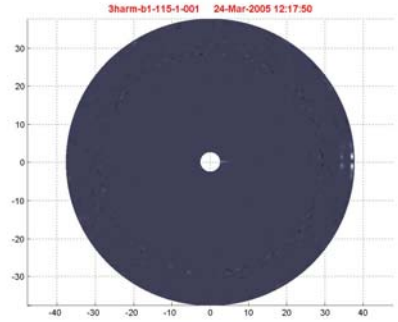



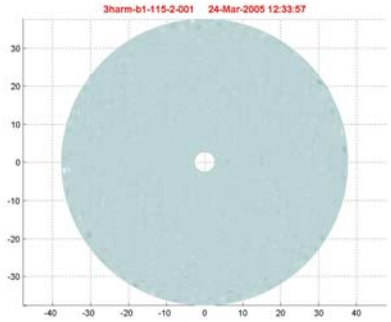
Disc 113 – side 1/2;

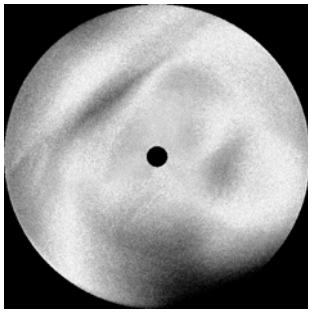
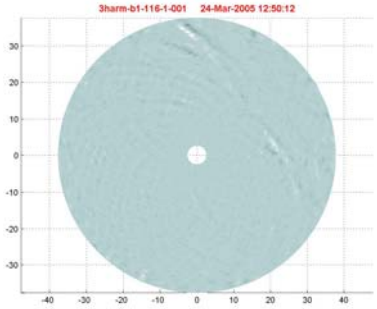



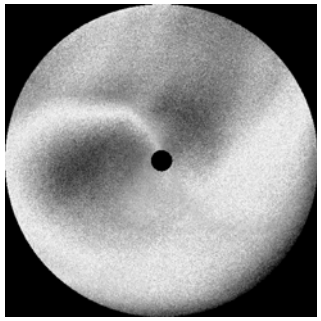
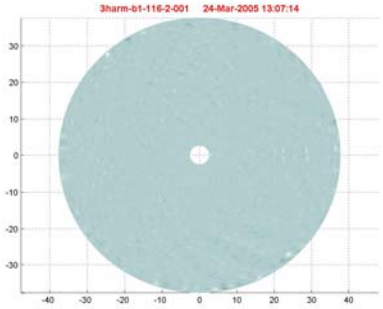
Disc 114 – side 1/2;

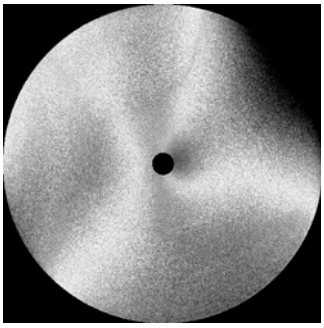
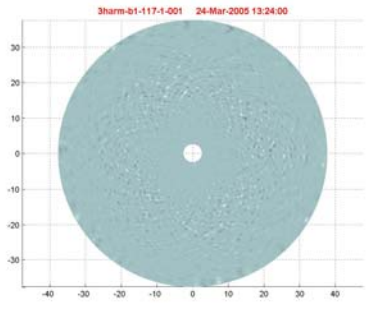


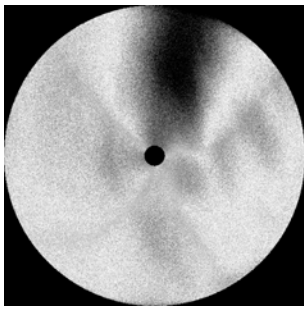
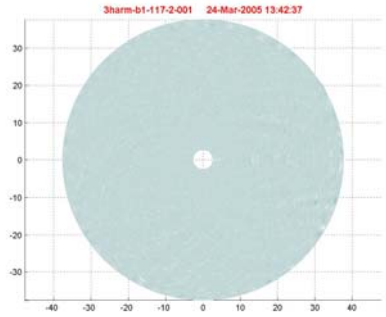
Disc 115 – side 1/2;

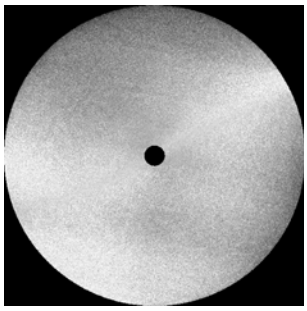
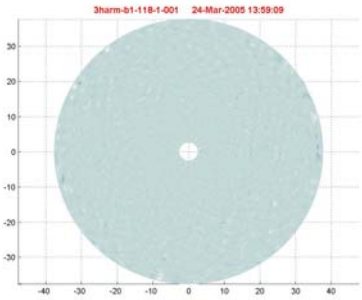



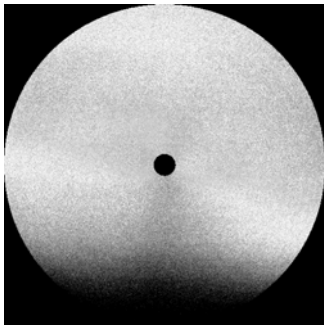
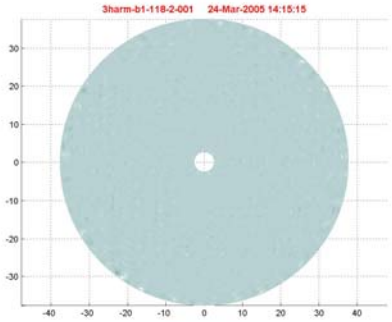
Disc 116 – side 1/2;

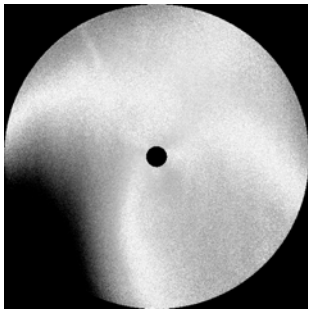
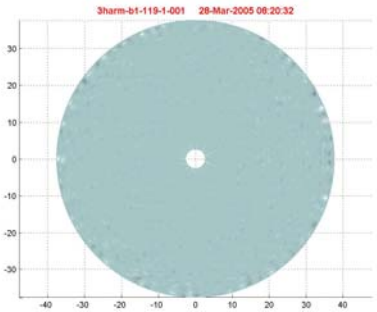



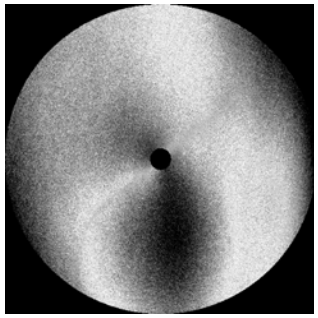
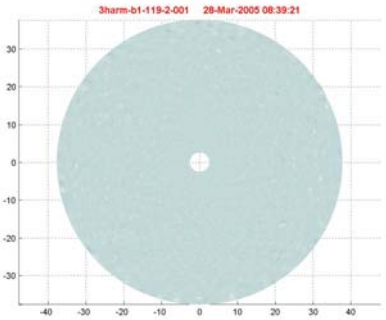
Disc 117 – side 1/2;

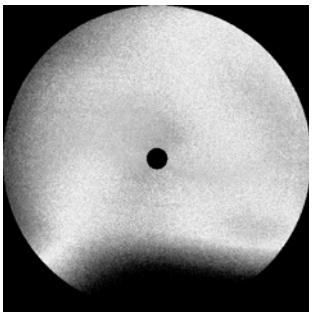
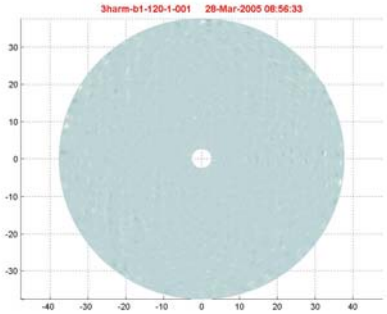



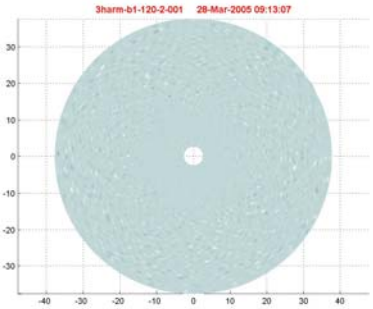
Disc 118 – side 1/2;

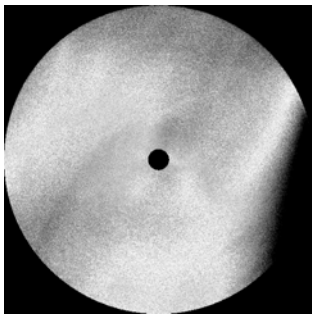
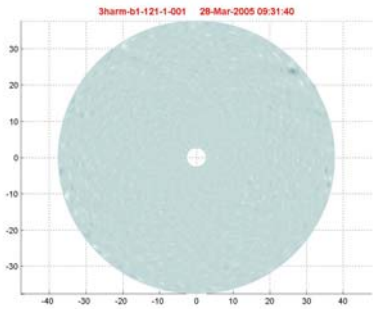



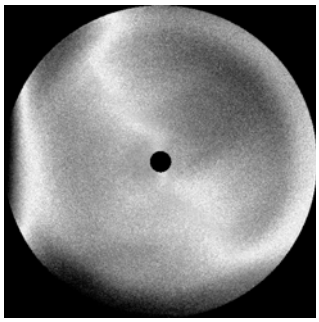
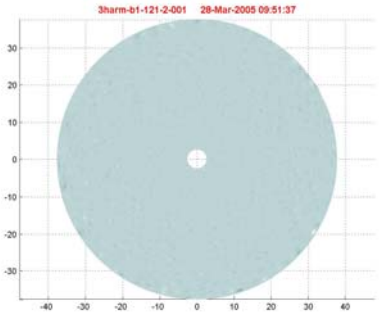
Disc 119 – side 1/2;

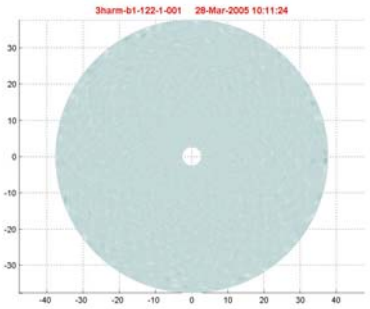



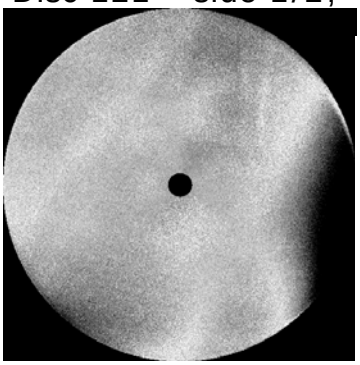
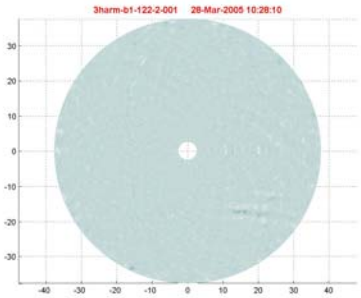
Disc 120 – side 1/2;

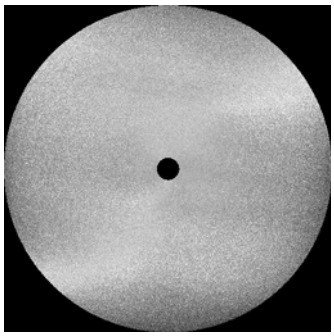
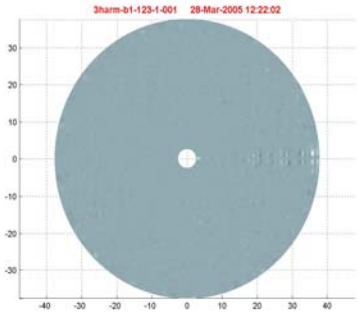



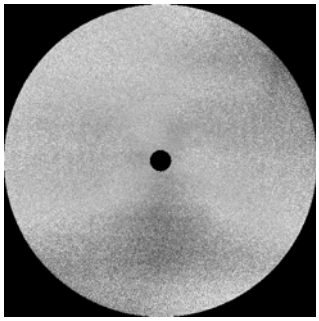
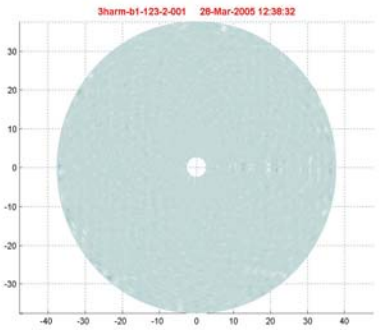
Disc 121 – side 1/2;



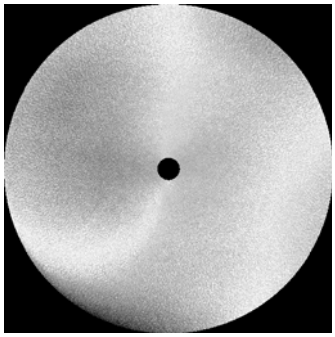
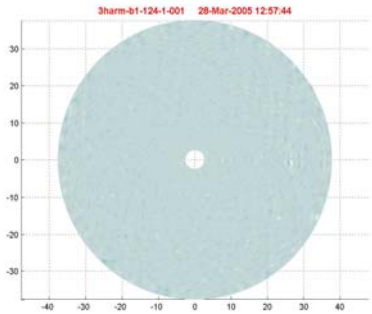



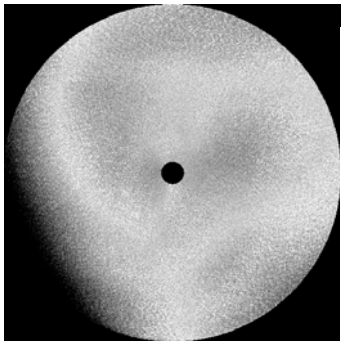
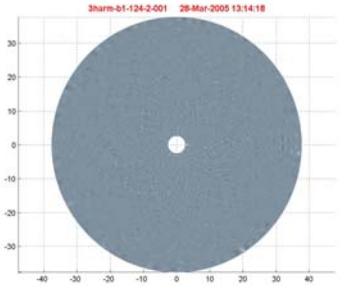
Disc 122 – side 1/2;

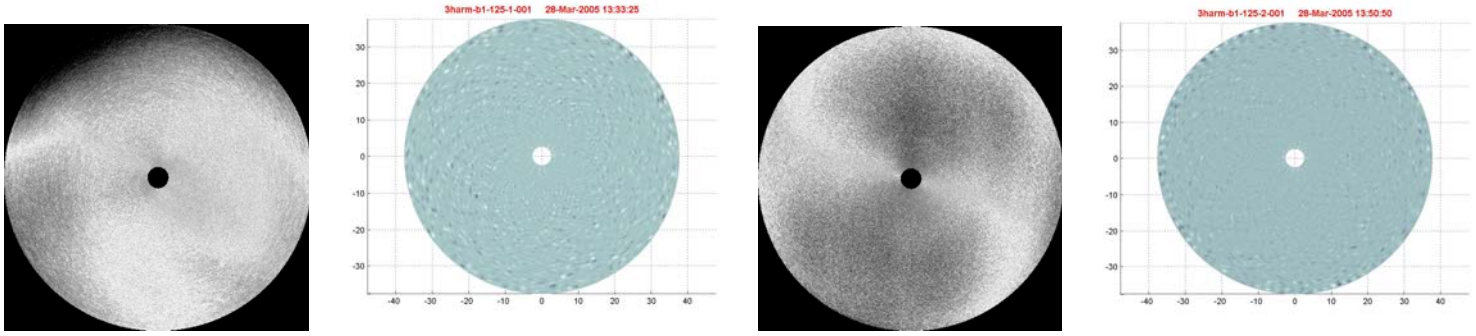



Disc 123 – side 1/2;

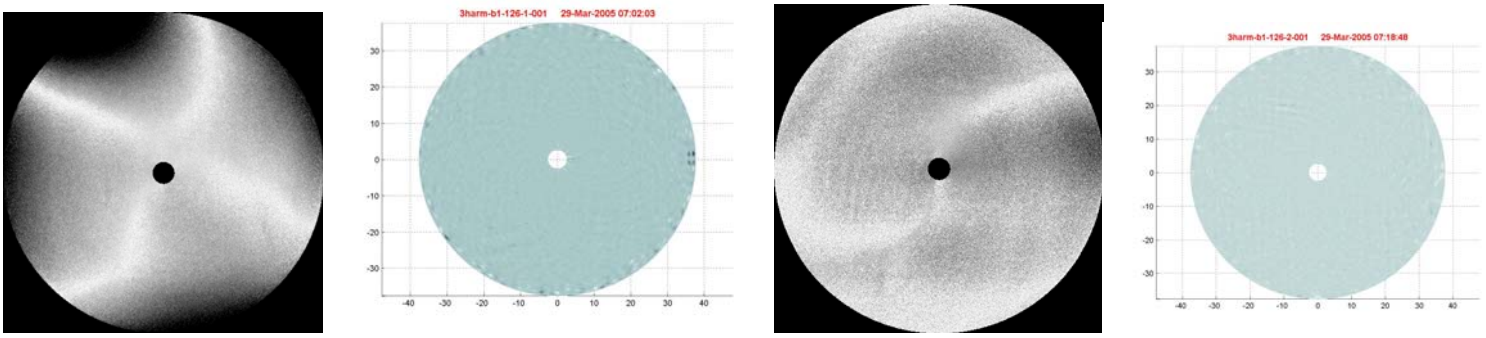



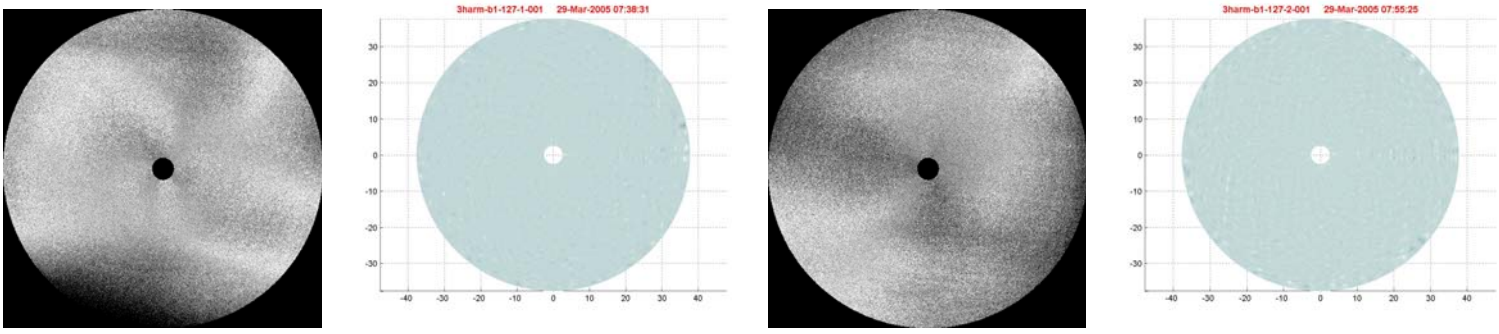
Disc 124 – side 1/2;



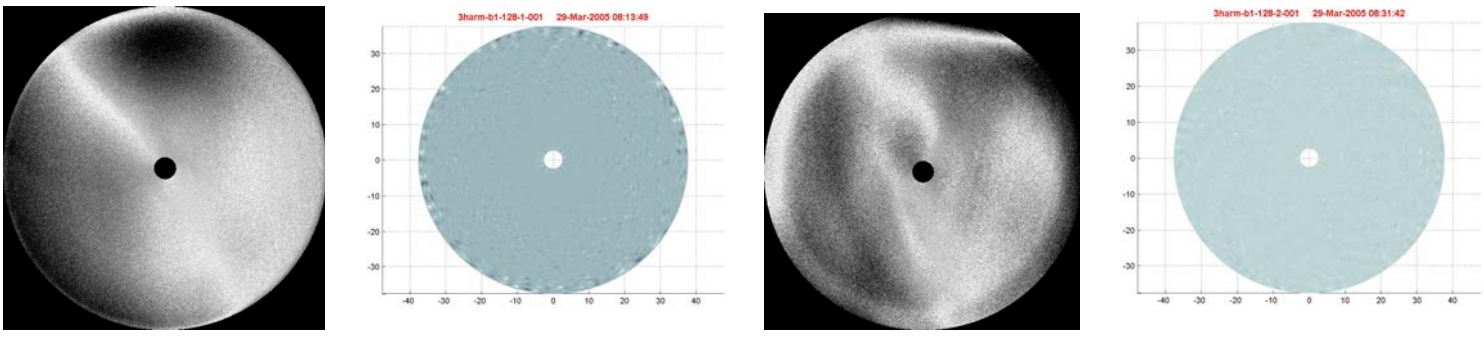
Disc 125 – side 1/2;



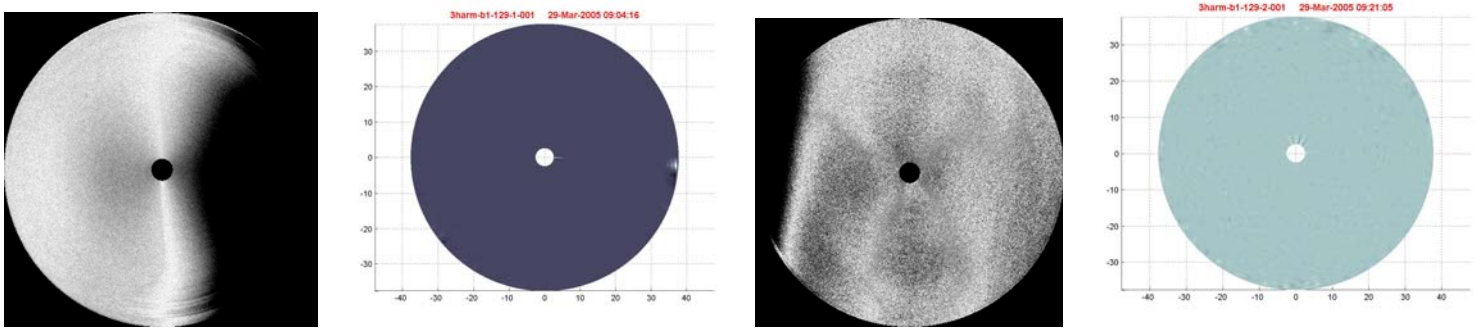
Disc 126 – side 1/2;



Disc 127 – side 1/2;



Disc 128 – side 1/2;



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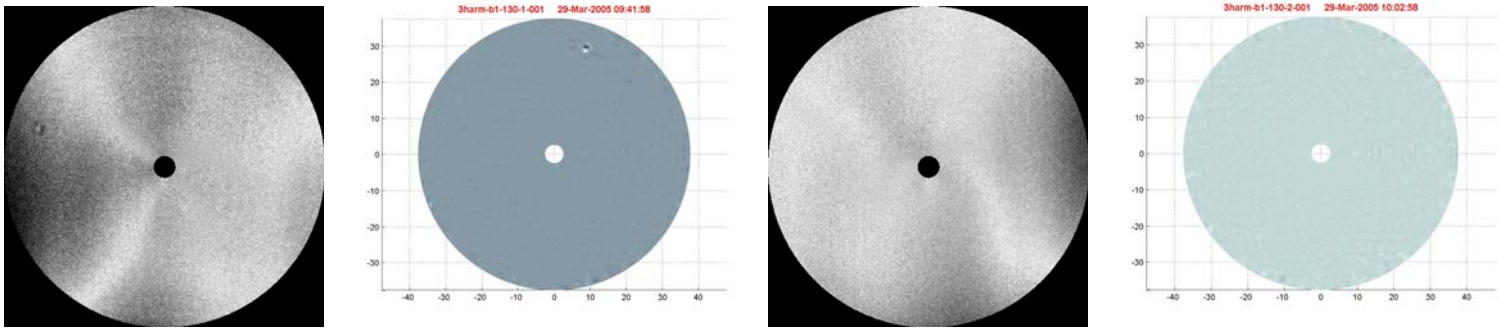
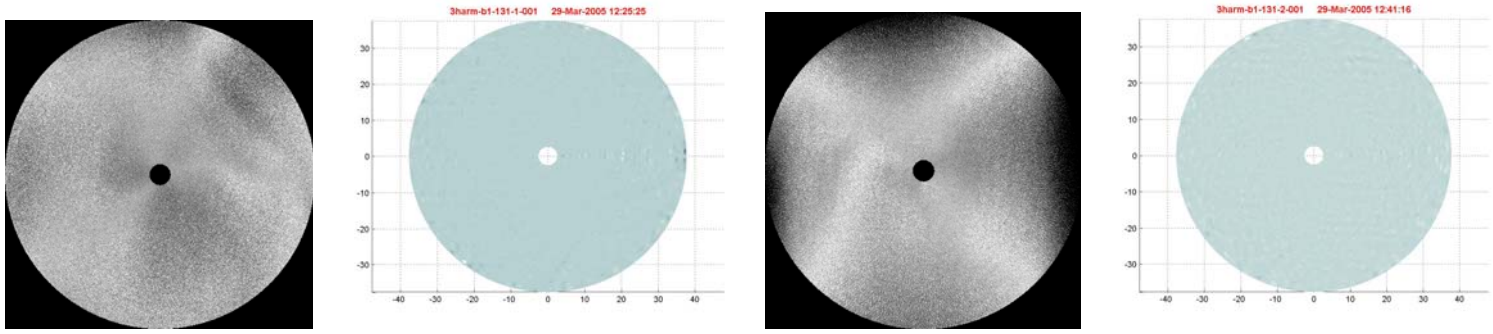


Disc 130 – side 1/2;



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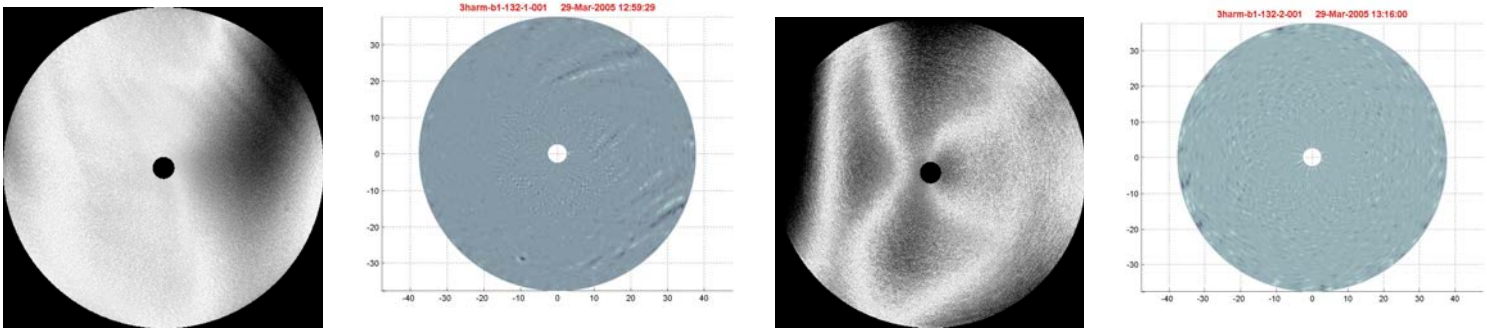
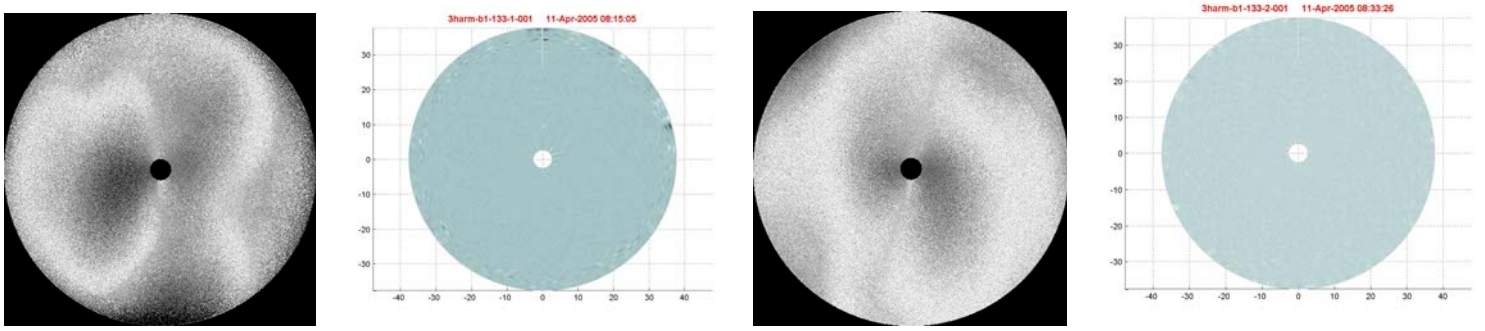


Disc 132 – side 1/2;



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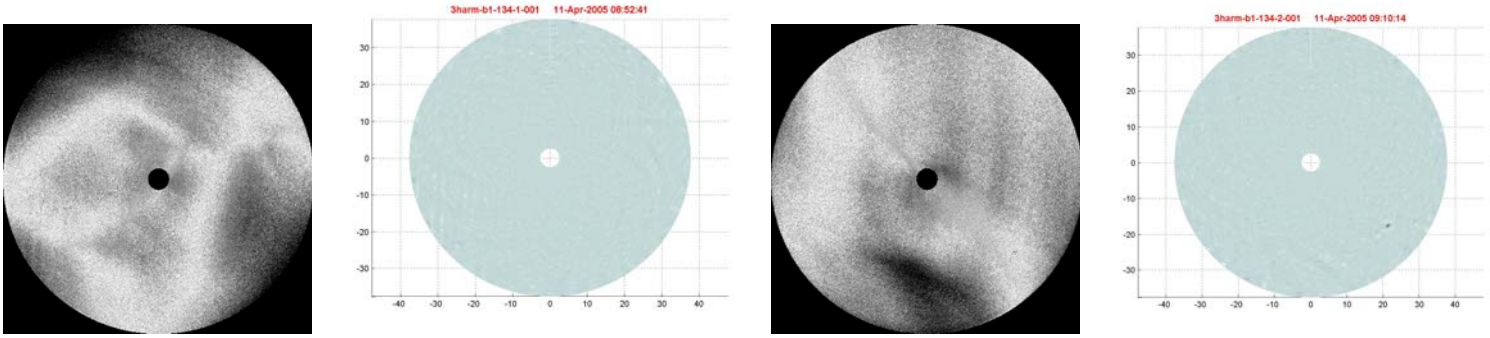

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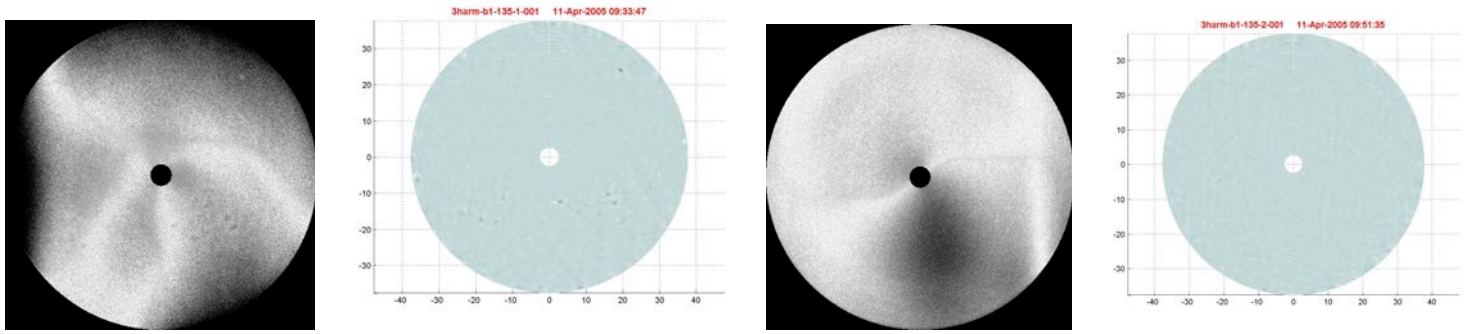
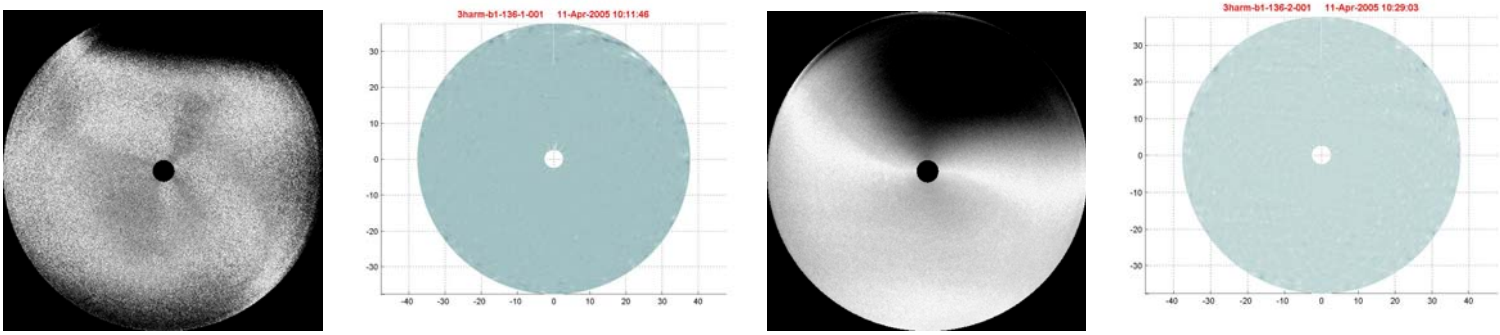
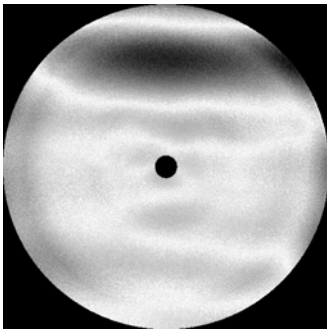
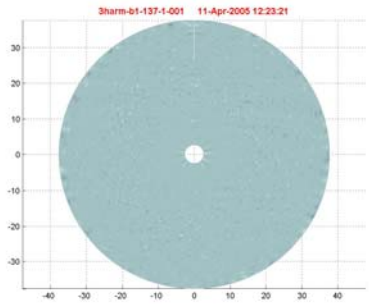
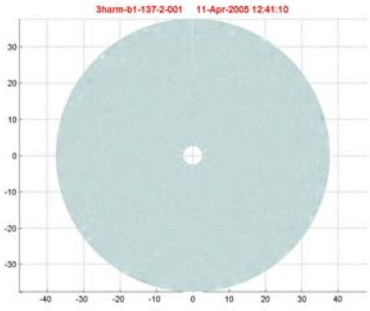


Disc 135 – side 1/2;

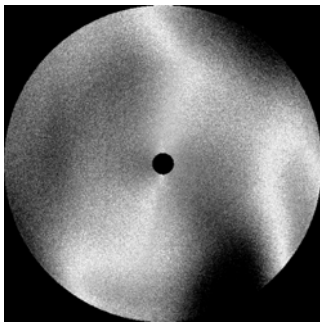
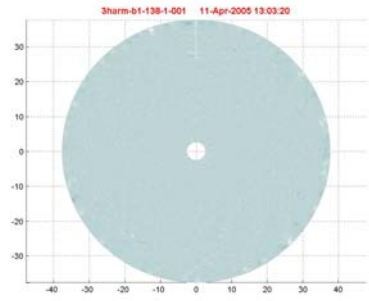


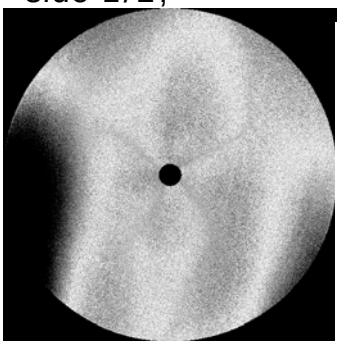
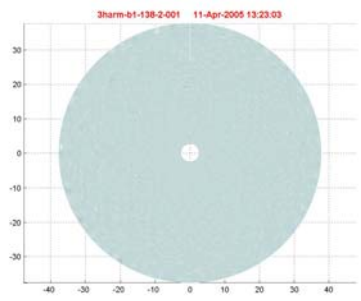
Disc 136 – side 1/2;

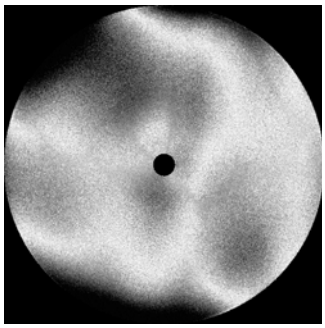
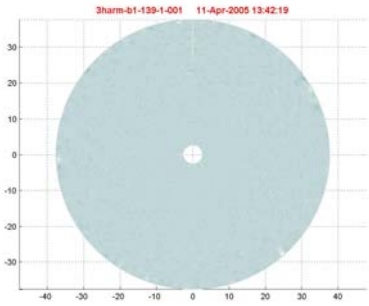



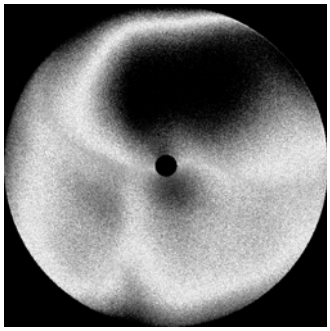
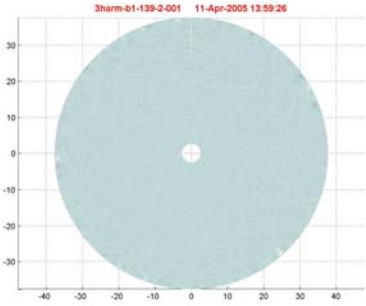
Disc 137 – side 1/2;

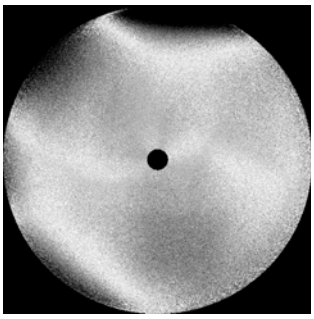
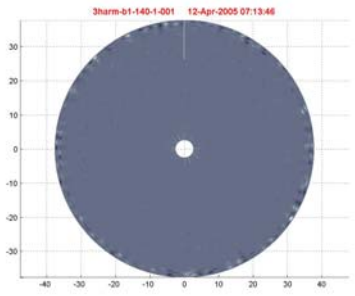



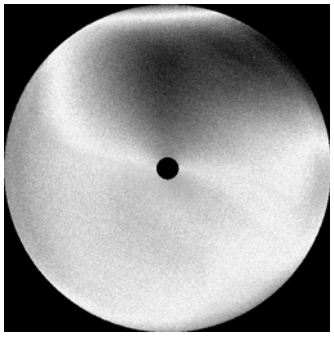
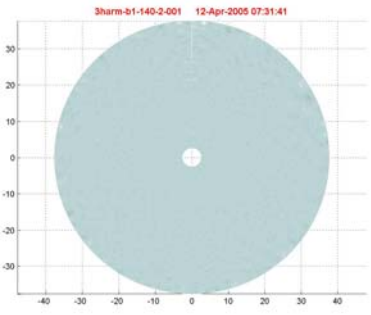
Disc 138 – side 1/2;

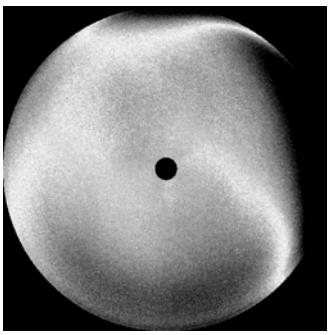
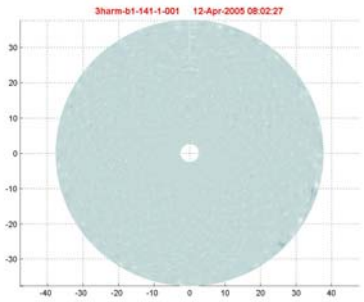



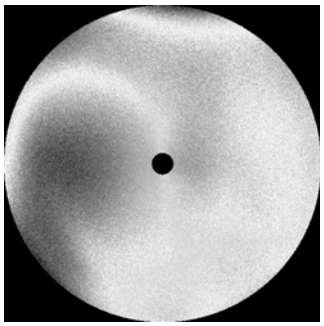
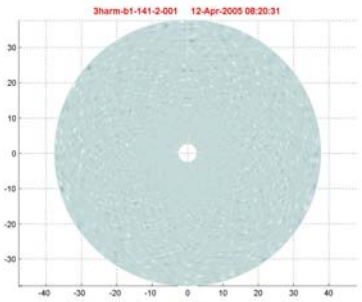
Disc 139 – side 1/2;

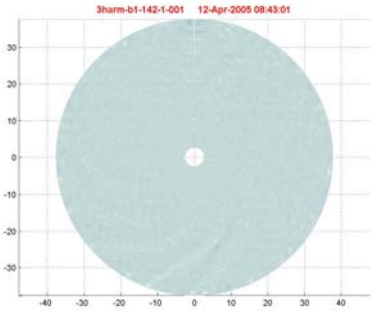



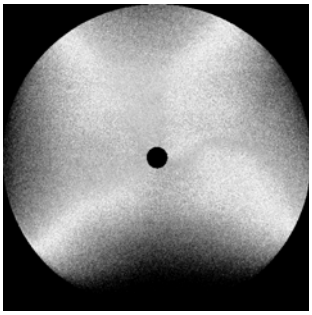
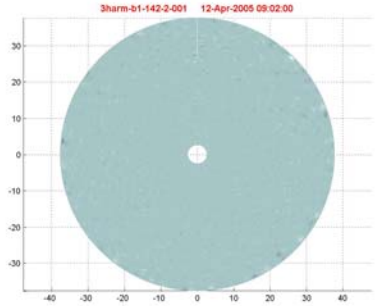
Disc 140 – side 1/2;

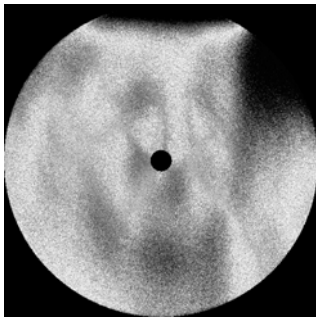
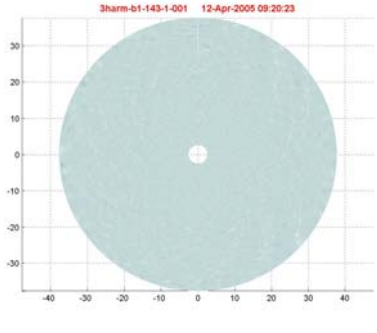



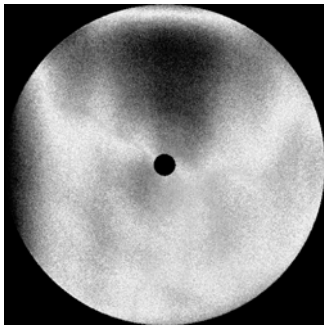
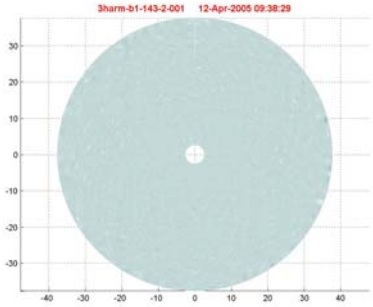
Disc 141 – side 1/2;

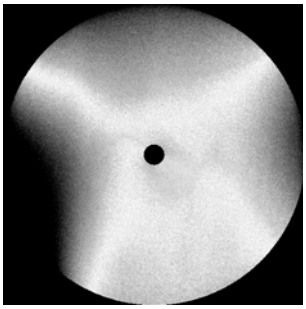
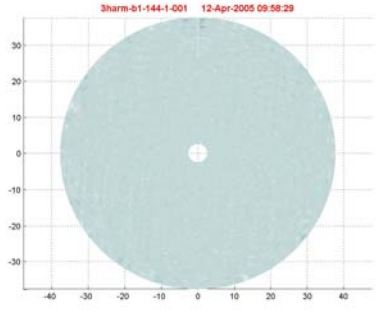



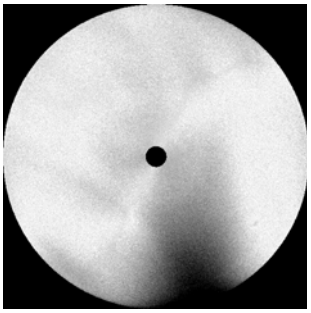
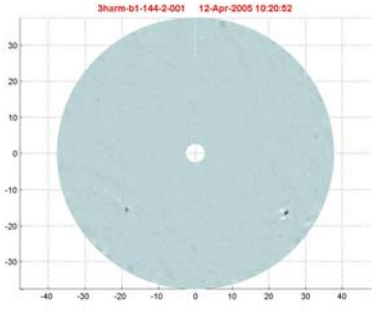
Disc 142 – side 1/2;

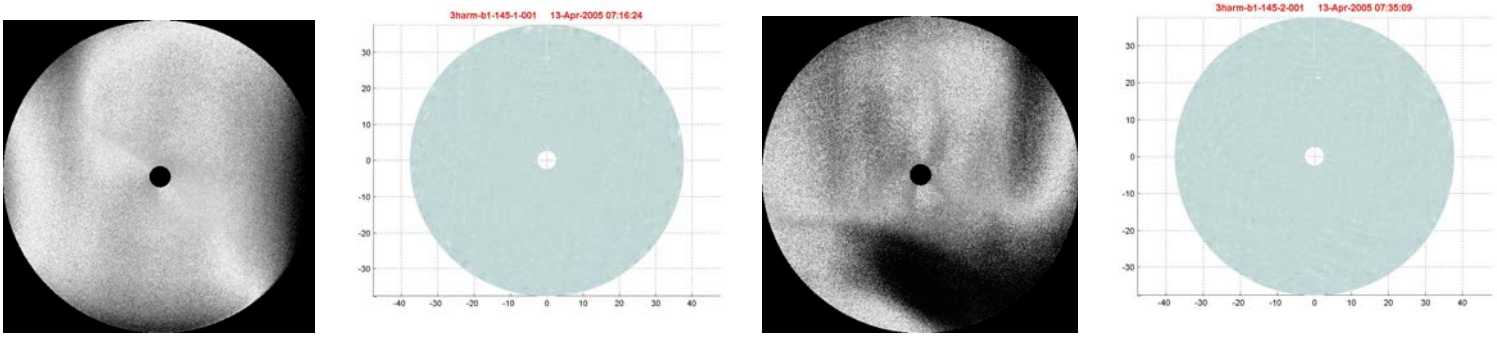



Disc 143– side 1/2;

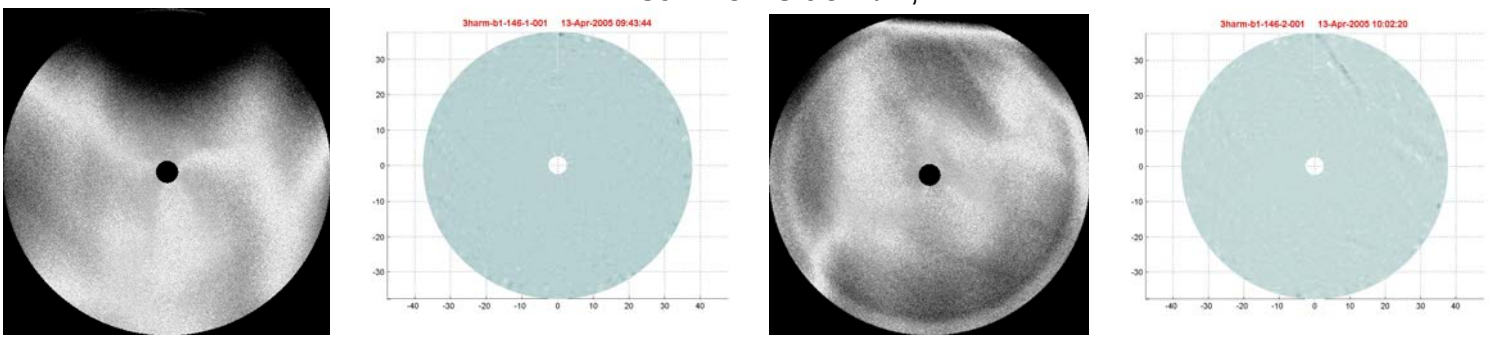



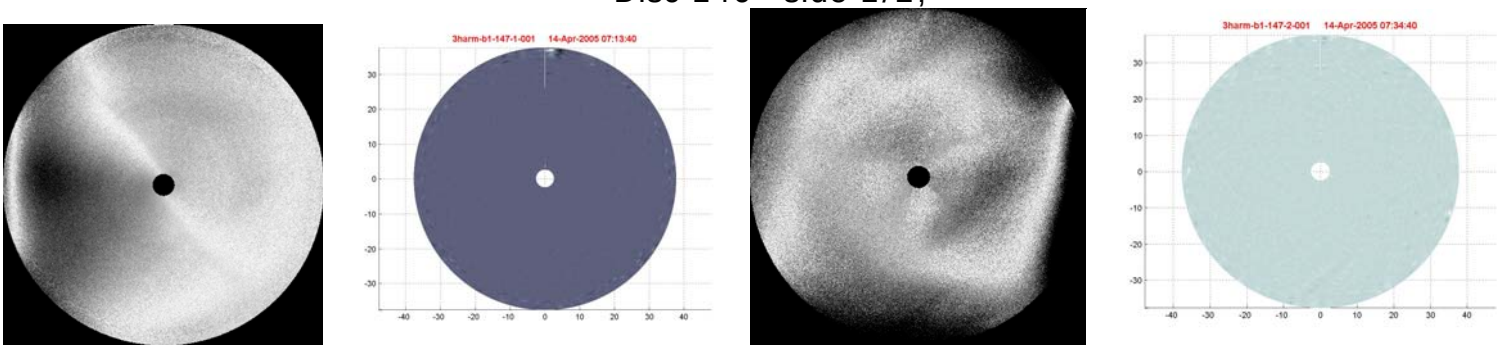
Disc 144– side 1/2;



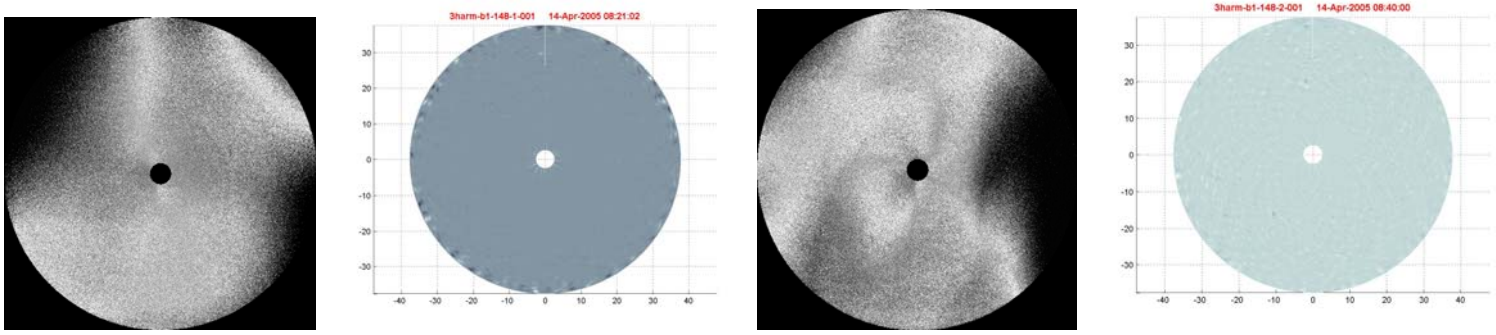
Disc 145– side 1/2;



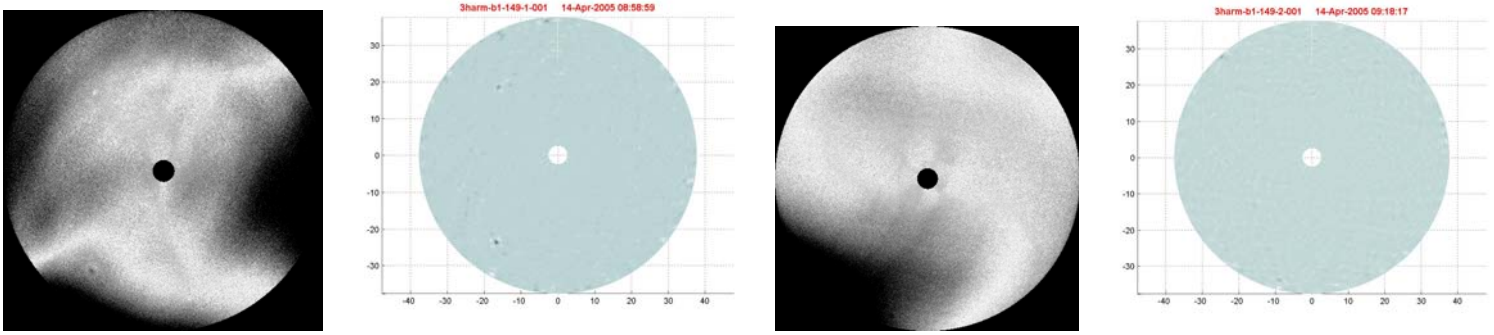
Disc 146– side 1/2;



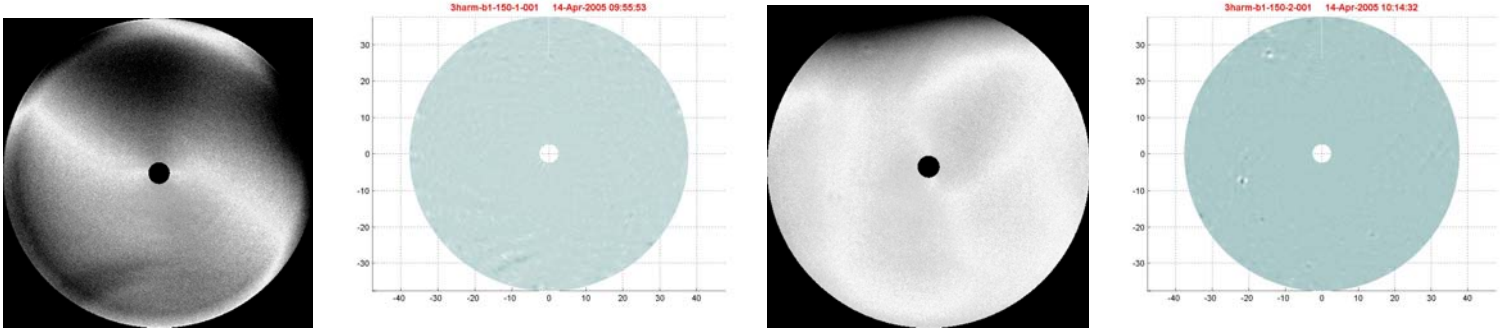
Disc 147– side 1/2;



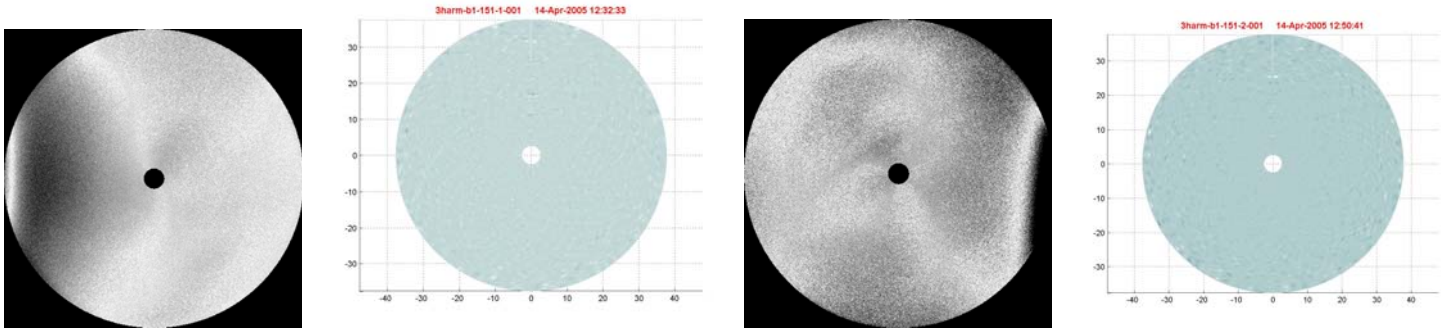
Disc 148– side 1/2;



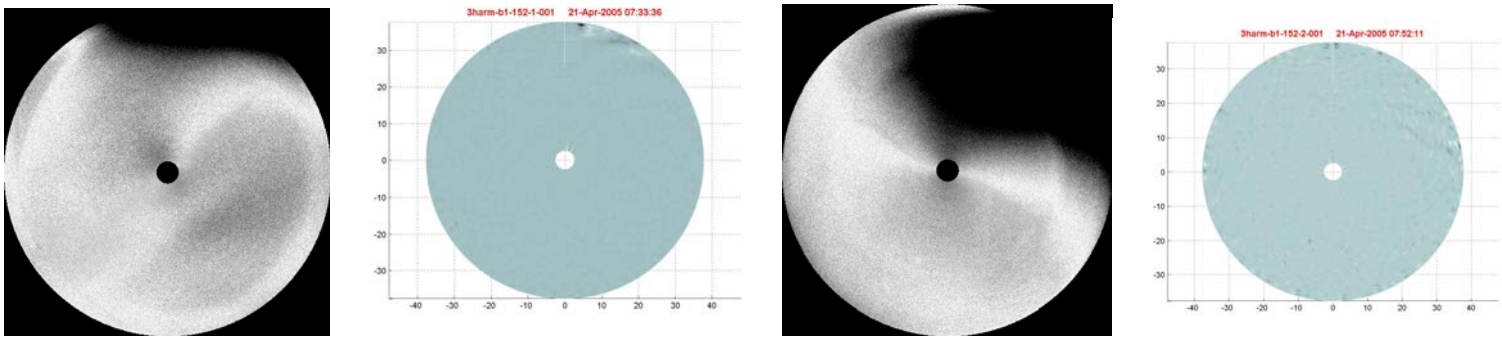
Disc 149– side 1/2;



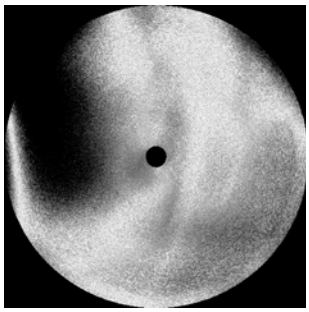
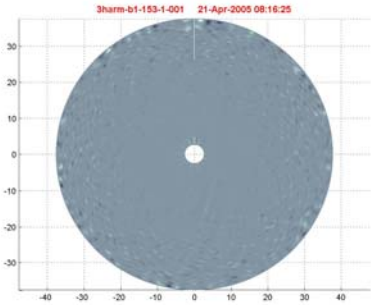
Disc 150– side 1/2;

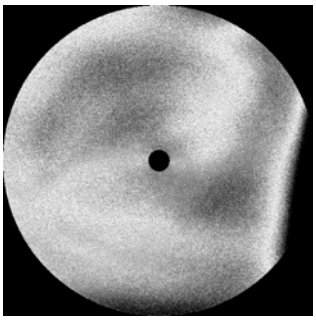
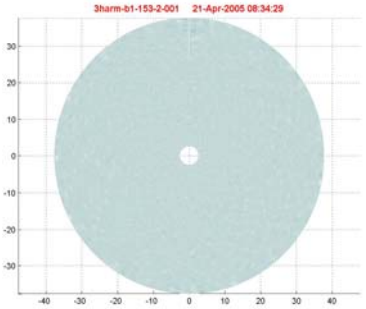


Disc 151– side 1/2;

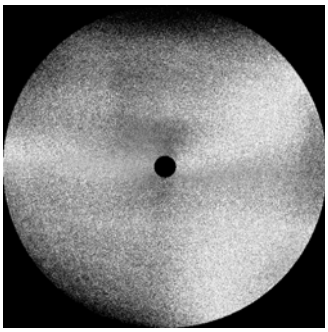
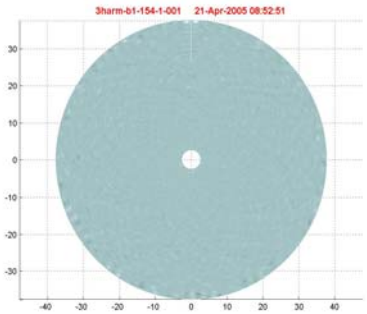


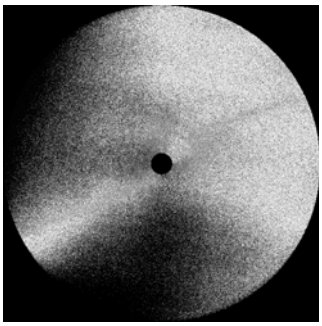
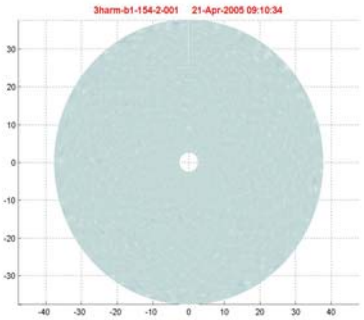
Disc 152– side 1/2;

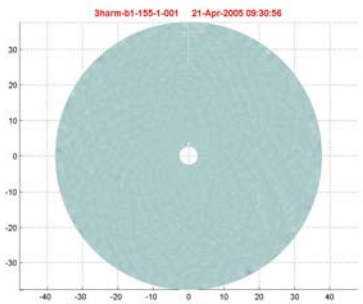



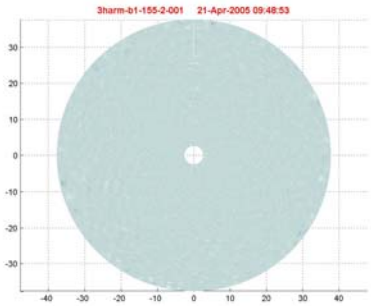
Disc 153– side 1/2;

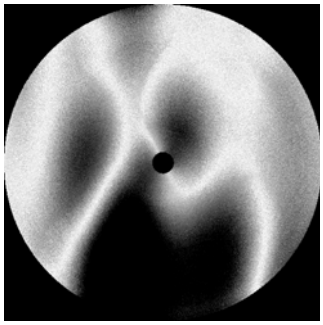
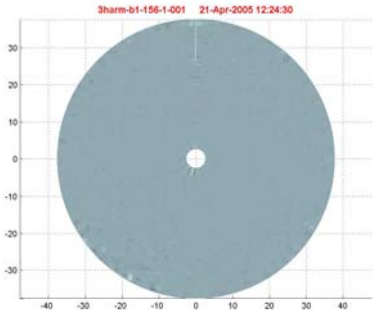



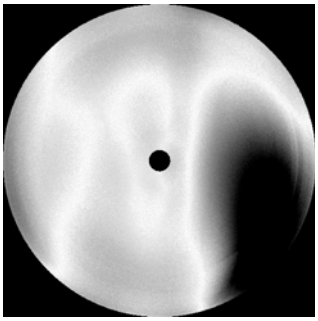
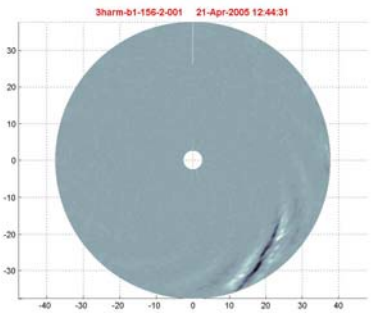
Disc 154– side 1/2;

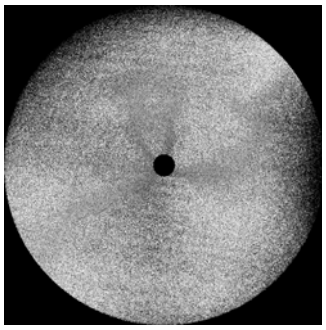
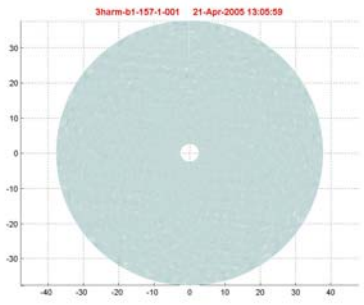



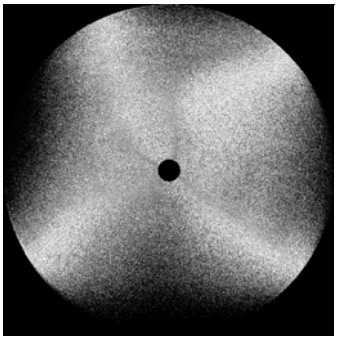
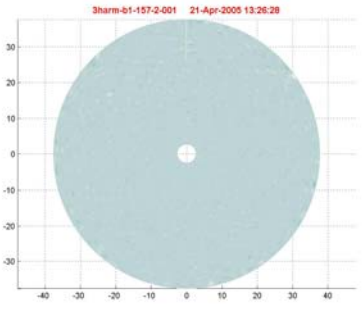
Disc 155– side 1/2;

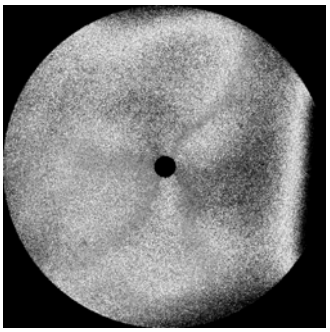
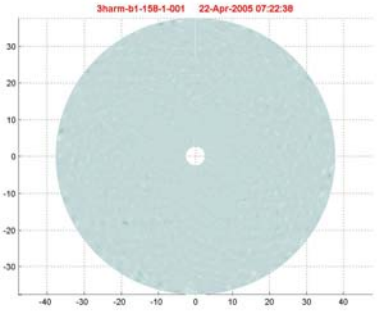



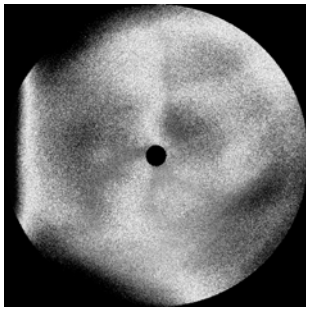
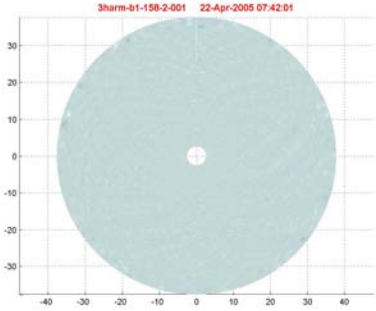
Disc 156– side 1/2;

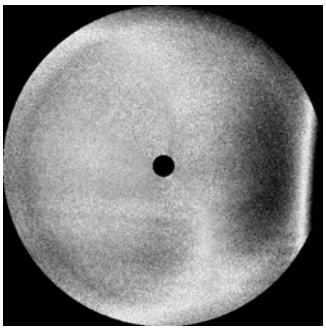
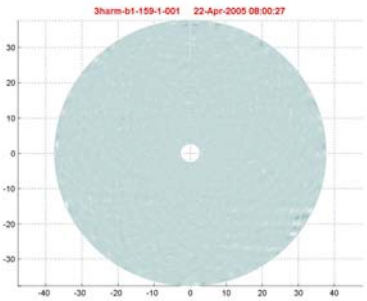



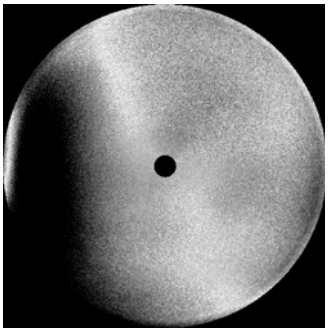
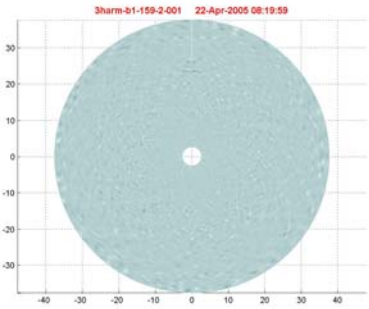
Disc 157– side 1/2;

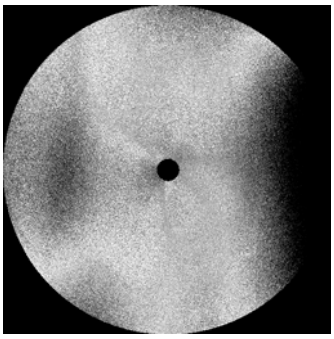
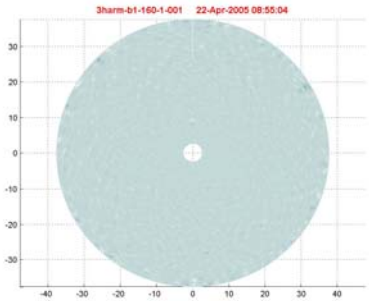



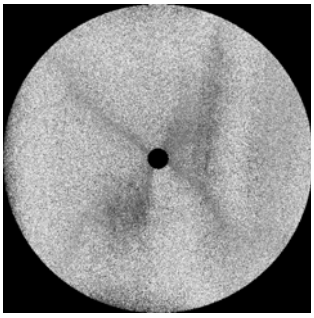
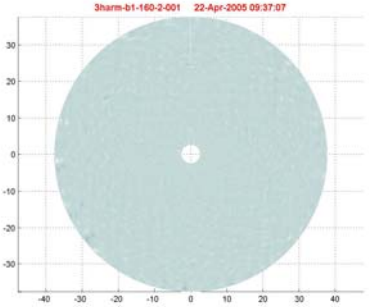
Disc 158– side 1/2;

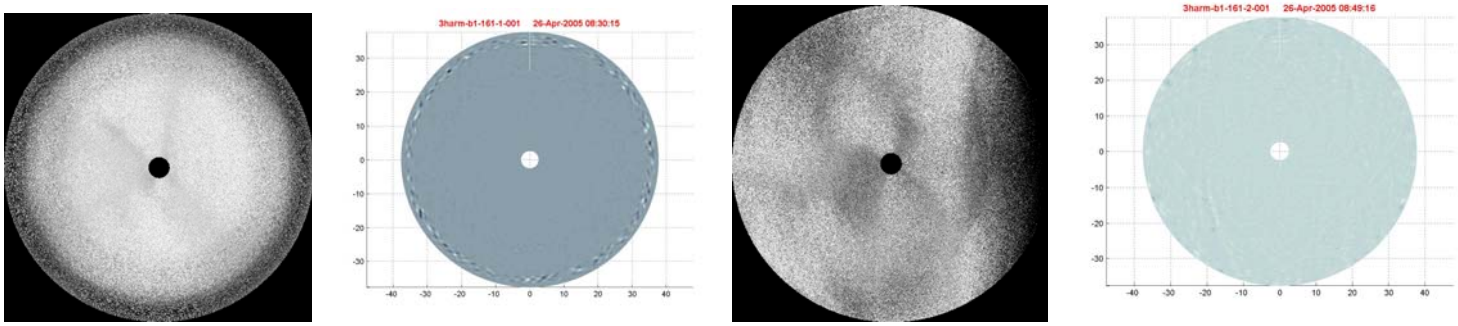



Disc 159– side 1/2;

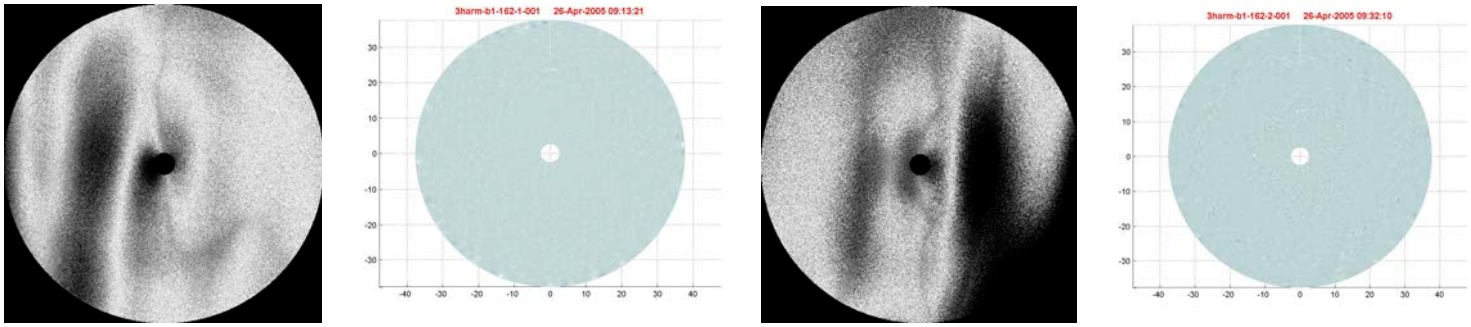



Disc 160– side 1/2;



Disc 161– side 1/2;



Disc 162– side 1/2;

3 SUMMARY TABLES

The following table summarizes the visual inspection and eddy current scans for the 3rd harmonic discs 73-162. The visual inspection was performed using a simple magnifying glass. The indicated numbers are approximate angle coordinates on the discs, where the angle is counted clockwise from the reference (12:00) position (line-mark) on the disc. OR stands for “outer rim”, that is the ~5 mm band at the outer rim of the disc. It is to be assumed that this area will be removed during subsequent production steps. MR stands for the ring in the middle, which will also be stamped out. HR stands for “half radius” and scratches, dents and pits in this area are more serious because this area will be used in the cavities. Most of the discs have oxidation along the edge as a result of the EDM cutting. This feature is not mentioned explicitly in the table below. The first columns of the table indicates out recommendation as to whether the disc should be used (black) or not (red). The disc number in the first columns is automatically red when both sides received a NO from the combined optical and ECS inspection in the last column. Furthermore each side is qualified with the **NO** label in the last column when clear signals appear in the ECS scan. The fact that the defects appear in the scanner indicates that they are sufficiently deep to cause concern. Although in the absence of a complete understanding of the nature of

these “defects” we cannot categorically exclude these discs from cavity fabrication, we recommend that these sides are not being used for the inside surface of a cavity cell. In a separate study (see section 4) the nature of the detected defects is further discussed. As will be shown there most of these defects are pits on the surface, which will most likely be removed by the subsequent surface processing.

disc	comment	OK ?
73	S1: Pits at 90 deg, 190 deg MR S2: Various pits/scratches 90 deg from C-OR	S1: NO S2: NO
74	S1: Various pits/scratches 90 deg from C-OR S2: OK	S1: NO S2: **OK**
75	S1: Ding at 280 deg MR S2: Various dings/scratches at 190 deg C-OR	S1: NO S2: NO
76	S1: OK S2: Pits/scratches through most of disk	S1: **OK** S2: NO
77	S1: Black specs 90 deg OR, 70 deg MR S2: OK	S1: NO S2: **OK**
78	S1: Edge scratch OR/MR 80 deg S2: Various scratches throughout disk(surface)	S1: NO S2: **OK**
79	S1: Various pits C-OR 90 deg S2: OK	S1: NO S2: **OK**
80	S1: OK S2: Slight scratches throughout disk, rollermarks from filter	S1: **OK** S2: **NO**
81	S1: Slight scratches around whole disk, 90 deg MR/OR, various pits S2: Slight scratches around whole disk	S1: NO S2: NO
82	S1: OK S2: Various pits 90 deg MR-OR, 180 deg C-MR	S1: **OK** S2: NO
83	S1: OK S2: Light surface scratches throughout, slight nick at 45 deg. MR	S1: **OK** S2: NO
84	S1: Light surface scratches, 180 deg MR-OR, scratch OR-MR 30 deg, pitting 45-160 deg, roller marks from filter S2: Light surface scratches, light pits throughout scratch at 50 deg OR	S1: **NO** S2: NO
85	S1: OK S2: Scratch MR/OR 165 deg	S1: **OK** S2: NO
86	S1: Various surface scratches throughout, various pits throughout, pits from filter S2: Tiny pits throughout	S1: NO S2: NO
87	S1: Surface scratches MR from 90-180 deg, MR 280 2 nicks S2: OK	S1: NO S2: **OK**
88	S1: Various pits throughout MR mainly 45-140 deg and 300-330 deg, pits from filter S2: OK	S1: **NO** S2: **OK**
89	S1: OK S2: Light surface scratches	S1: **OK** S2: NO
90	S1: Light surface scratches S2: Pit at 180 deg MR	S1: **OK** S2: NO

91	S1: Light surface scratches S2: Light surface scratches	S1: **OK** S2: **OK**
92	S1:Ding center S2:Ding 90 deg MR deep	S1: **OK** S2: NO
93	S1: Various pits throughout, ding at180 deg MR S2: Various pits throughout, pits from filter	S1: NO S2: **NO**
94	S1: OK S2: Light surface scratches	S1: **OK** S2: NO
95	S1: Light surface scratches S2: OK	S1: NO S2: **OK**
96	S1: Light surface scratches, roller marks from filter S2: Dings MR/OR 200 deg, MR 260 deg	S1: NO S2: NO
97	S1: Light surface scratches S2: Light surface scratches, roller marks from filter	S1: **OK** S2: **NO**
98	S1: Pit at 70 deg, pits from filter S2: Pit at 290 deg MR, 340 deg MR	S1: NO S2: NO
99	S1: OK S2: Light surface scratches, roller marks from filter	S1: **OK** S2: NO
100	S1: Light surface scratches S2: Light surface scratches, roller marks from filter	S1: **OK** S2: **NO**
101	S1: Black spec/pits at 270 deg MR, various pits throughout 20-160 deg, pits from filter S2: Light surface scratches	S1: **NO** S2: **OK**
102	S1: Light surface scratches S2: Light surface scratches, pit center	S1: **OK** S2: NO
103	S1: Ding center, roller marks and defect from Filter S2: OK	S1: NO S2: **OK**
104	S1: Tiny pits throughout, scratch at 45 deg OR S2: Light surface scratches	S1: NO S2: **OK**
105	S1: Light surface scratches, roller marks from filter S2: Light surface scratches	S1: **NO** S2: **OK**
106	S1: Light surface scratches, roller marks from filter S2: Light surface scratches, roller marks from filter, irregular thickness	S1: **NO** S2: **NO**
107	S1: Light surface scratches, defect from filter S2: Various pits throughout, roller marks from filter	S1: **NO** S2: NO
108	S1: Tiny pits throughout, light surface scratches S2: Pit at 45 deg MR, light surface scratches IRREGULAR THICKNESS	S1: NO S2: NO
109	S1: Light surface scratches S2: Light surface scratches, tiny pits throughout	S1: **OK** S2: NO
110	S1: Tiny pits throughout S2: Various pits throughout, light surface scratches	S1: NO S2: NO
111	S1: Very tiny pits throughout S2: OK IRREGULAR THICKNESS	S1: **OK** S2: **OK**
112	S1: Pits OR/MR 310 deg, DIRTY, faint roller marks, IRREGULAR THICKNESS S2: OK , DIRTY	S1: NO S2: **OK**

113	S1: Roller marks from filter S2: Light surface scratches, tiny pits throughout, DIRTY	S1: **NO** S2: NO
114	S1: Scratch at 250 deg OR/MR, various pits throughout S2: Various pits throughout, light surface scratches	S1: NO S2: NO
115	S1: Very tiny pits throughout S2: Very tiny pits throughout	S1: **OK** S2: **OK**
116	S1: Tiny pits throughout, light surface scratches, roller marks from filter S2: Tiny pits throughout, light surface scratches	S1: **NO** S2: **OK**
117	S1: 10 deg MR Ding and 2 scratches S2: Scratch at 270 deg MR-OR, light surface scratches, faint roller marks	S1: NO S2: NO
118	S1: Tiny pits throughout S2: Tiny pits throughout, scratch at 330 deg MR, light surface scratches	S1: **OK** S2: NO
119	S1: Light surface scratches, tiny pits throughout S2: Light Surface scratches , tiny pits throughout	S1: **OK** S2: **OK**
120	S1: Light surface scratches, tiny pits throughout, faint roller marks S2: Light surface scratches, tiny pits throughout	S1: **OK** S2: **OK**
121	S1: Light surface scratches, tiny pits throughout, faint roller marks IRREGULAR THICKNESS S2: Light surface scratches, tiny pits throughout	S1: **OK** S2: **OK**
122	S1: Light surface scratches S2: Light surface scratches, roller marks from filter	S1: **OK** S2: NO
123	S1: Tiny pits throughout, scratch at 50 deg MR S2: Light surface scratches, tiny pits throughout, ding at 70 deg MR	S1: **OK** S2: NO
124	S1: Light surface scratches S2: Light surface scratches, black spot at 190 deg MR	S1: **OK** S2: NO
125	S1: Light surface scratches S2: Scratch through disk 0-180 deg	S1: **OK** S2: NO
126	S1: Light surface scratches, nick at 80 deg OR S2: Light surface scratches, faint roller marks	S1: **OK** S2: **OK**
127	S1: Light surface scratches S2: Light surface scratches	S1: **OK** S2: **OK**
128	S1: Light surface scratches, scuffs or nicks in center, scratch at 280 deg MR S2: Light surface scratches, faint roller marks	S1: NO S2: **OK**
129	S1: Light surface scratches, tiny pits throughout S2: Light surface scratches, tiny pits throughout IRREGULAR THICKNESS	S1: **OK** S2: **OK**
130	S1: Light surface scratches, tiny pits throughout, ding at 280 deg MR, defect from filter S2: Light surface scratches, tiny pits throughout, ding at 140 deg MR and OR	S1: **NO** S2: NO
131	S1: Light surface scratches, DIRTY S2: Light surface scratches	S1: **OK** S2: **OK**
132	S1: Light surface scratches, a little deeper than normal, ding at 100 deg MR, roller marks and defect from filter S2: Light surface scratches, ding at 5 deg MR close to center	S1: **NO** S2: NO

133	S1: Dirty, scratch at 320 deg MR S2: Dirty	S1: NO S2: OK
134	S1: Light surface scratches S2: Pits MR between 90-180 deg, defect at 110 deg as seen from filter	S1: OK S2: NO
135	S1: Pits throughout, 9 defects, mostly lower half, one at 40 deg as seen from filter S2: Tiny pits throughout	S1: NO S2: NO
136	S1: Tiny pits throughout, light surface scratches, ding at 110 deg MR S2: Tiny pits throughout	S1: NO S2: OK
137	S1: Light surface scratches S2: Light surface scratches, dirty, ding at 355 deg MR	S1: OK S2: NO
138	S1: Dirty, light surface scratches S2: Dirty	S1: OK S2: OK
139	S1: Dirty, light surface scratches S2: Dirty, light surface scratches	S1: OK S2: OK
140	S1: Dirty S2: Dirty, light surface scratches, black spot at 0 deg MR scratch at 10 deg MR	S1: OK S2: NO
141	S1: Very tiny pits S2: Light surface scratches	S1: OK S2: OK
142	S1: Faint roller marks at 180 deg as seen from filter S2: None	S1: NO S2: OK
143	S1: Light surface scratches S2: Light surface scratches	S1: OK S2: OK
144	S1: Light surface scratches, various tiny pits throughout S2: Various deep pits throughout, defects at 110 and 220 deg as seen from filter	S1: OK S2: NO
145	S1: Light surface scratches, various pits throughout S2: Light surface scratches, various pits throughout	S1: OK S2: OK
146	S1: Light surface scratches, ding at 160 deg MR S2: Light surface scratches, roller mark at 10 deg as seen from filter	S1: NO S2: NO
147	S1: Light surface scratches, pits at 80 deg and 85 deg MR S2: Light surface scratches, dirty, faint roller mark as seen from filter	S1: NO S2: OK
148	S1: Light surface scratches, dirty, tiny pits throughout S2: Light surface scratches, ding at 0 deg MR and 220 deg MR and 10 deg MR, defects at 190 and 360 deg as seen from filter	S1: OK S2: NO
149	S1: Light surface scratches, tiny pits throughout, defects at 200 and 320 deg as seen from filter S2: OK	S1: NO S2: OK
150	S1: Light surface scratches, tiny pits throughout, roller marks at 190 deg as seen from filter S2: Pits throughout, light surface scratches, black spot at 270 deg MR , defects at 150 ,180 , 200, 250 , 260 , 350, as seen from filter	S1: NO S2: NO
151	S1: Light surface scratches, tiny pits throughout S2: Light surface scratches, tiny pits throughout	S1: OK S2: OK
152	S1: Scratch at 20 deg MR, pits throughout, disk irregularity at 0 deg as seen from filter S2: Tiny pits throughout, very faint roller marks at 45 deg, defect at 190, upper half may be thicker as seen from filter	S1: NO S2: NO

153	S1: Slight nick at 355 deg MR S2: Light surface scratches	S1: **OK** S2: **OK**
154	S1: Light surface scratches, tiny pits throughout S2: Light surface scratches, tiny pits throughout	S1: **OK** S2: **OK**
155	S1: Light surface scratches S2: Light surface scratches	S1: **OK** S2: **OK**
156	S1: Dirty, ding at 180 MR S2: Dirty, strong roller marks as seen from filter	S1: NO S2: **NO**
157	S1: OK S2: OK	S1: **OK** S2: **OK**
158	S1: faint defect at 210 deg as seen from filter S2: Ding at 290 deg MR-OR	S1: NO S2: NO
159	S1: OK S2: Tiny pits throughout	S1: **OK** S2: **OK**
160	S1: Tiny pits throughout S2: OK	S1: NO S2: NO
161	S1: DIRTY S2: Tiny pits throughout, faint roller marks at 200 deg as seen from filter	S1: **OK** S2: NO
162	S1: Tiny pits throughout S2: Light surface scratches	S1: **OK** S2: **OK**

The above table can be summarized in the following way: From the 90 discs, 21 (23%) give no signal (**OK**) and 22 discs (25%) give signals on both sides (NO or **NO**). Therefore 69 discs (76%) have at least one side giving a signal. 74 sides (41%) have visible pits (of which only 25% appear in the eddy current scans), 112 sides (62%) have scratches, 27 sides (15%) have roller marks (which only appear in the eddy current scans).

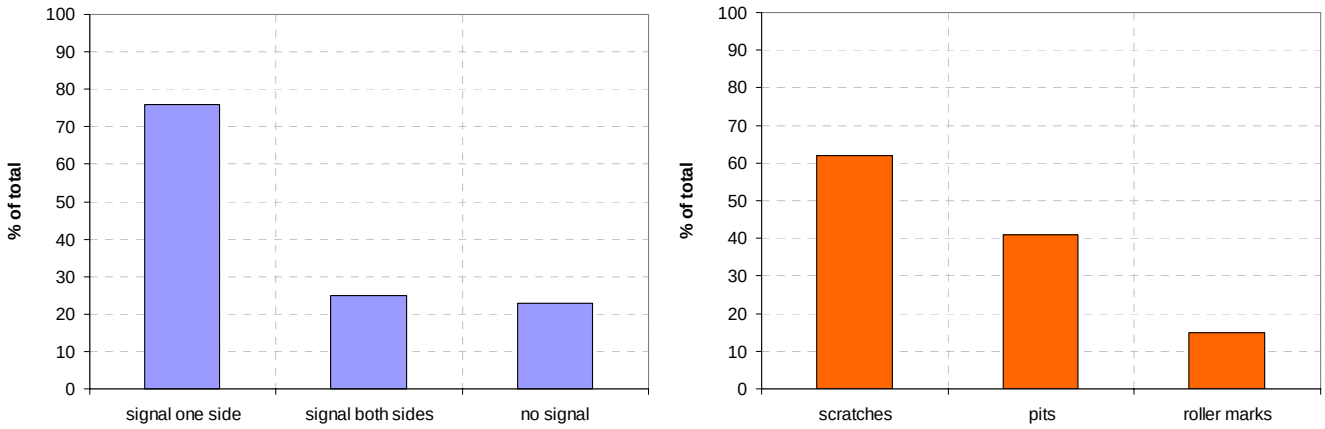


Figure 3: Evaluation summary of 3rd harmonic cavity blanks based on eddy current scans and optical inspections. Left: Percent of discs with signals on one, both or no side. Right: Percent of sides with scratches, pits and "rollermarks".

4 SPECIAL MEASUREMENTS

We believe that scratches and pits, which are mostly visible to the naked eye, are the dominant types of defects detected either with eddy current scanning or simple visual inspection. Such defects may well be removed in the subsequent processing that is part of the cavity fabrication procedure. A series of measurements previously performed with another set of discs[5], which consisted in etching the discs and repeating the scan, gave ambiguous results. With the recent set of samples we performed profilometric and chemical measurements to improve our understanding of the surface pits. The current model is that they originate in the rolling process when single grains are ripped from the sheet by the rollers, which subsequently adhere to the rollers and cause further damage via imprints. An alternate model is that of the gas bubble in the melted ingot, which condenses as the ingot solidifies. Chemical residues of the original gas are expected in the crater linings in this case. EDX studies did not provide us with any evidence of such chemical residues in the "crater-walls".

Profilometric measurements were performed on discs 134, 135, 144, 148, 149 and 150 to estimate the depth of the etching pits. These pits vary from 0.2 to 0.5 mm in width and from 10-90 microns in depth. Appendix 1 lists the sum of the data. These profiles would indicate that subsequent etching of ~120 microns would remove them, such as was found in one case in the previous study (in the other case such an etch was not sufficient). The so called "roller-marks" did no give any measurable profile (our equipment for profilometric measurement might not be capable of detecting long range effects, however).

Figure 4 shows the results of eddy current scans performed with the SNS/FNAL scanner on disc 14 before and after removing 175 μm with BCP etching. The plots clearly show a change of appearance of the scan, possibly a result of the increase of surface roughness due to the BCP etching. Also, and this is corroborated by simple visual inspection, most defects are still present after etching. This result indicates that the defects found in some blanks from this batch will not be removed by the subsequent etching steps and that these particular disc-sides should not be used for the inside of the cavities.

[5] P. Bauer et al., "Eddy Current Scanning Report – FNAL-3rdHarmonic Cavity #2", Fermilab Technical Division Internal Note TD-04-039, Revision 1, 03/05.

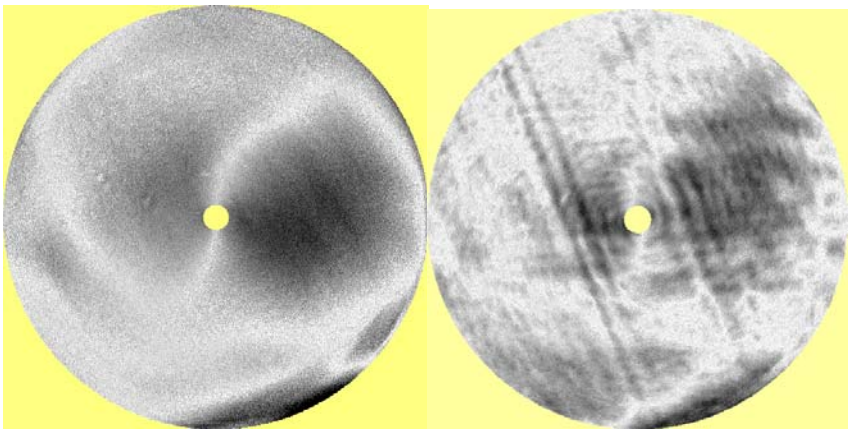


Figure 4: Scan of disc 14/2 before (left) and after (right) 175 μm were removed with BCP etching.

A chemical analysis with EDX of the first micron of the crater-lining surface in the pit of disc 134 (side 2) revealed no difference to the rest of the surface. Figure 5 shows an SEM image of this (shallow) pit.

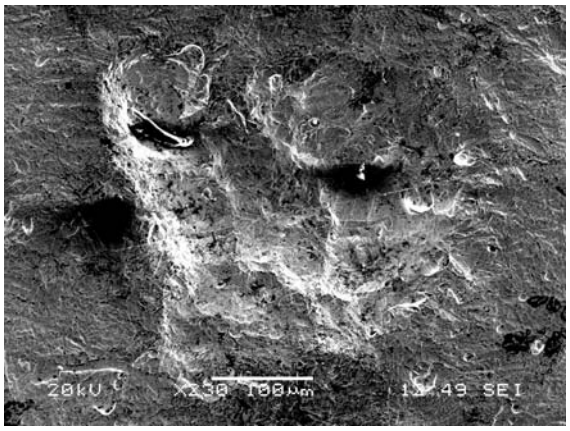


Figure 5: SEM pic of surface pit in disc 134-side 2.

5 SUMMARY

All 90 discs discussed in this report were scanned with the SNS/FNAL eddy-current scanner and visually inspected. Defect-signals were found on both sides in 22 of the discs. 21 discs had no defect on any side. 69 discs therefore had a problem on at least one side. The typical defects found are surface pits (all detected visually and 25% detected by the eddy current method), scratches and roller marks (detected with the eddy current method only). The summary table in section 3 contains the detailed findings of the testing and also includes a rating. This rating, however, is not final, since many of the surface defects may well be removed by the typical surface processing steps applied during cavity fabrication. We recommend, however, that the sides labeled with **NO** in the last column of the table should not be used as the inside surfaces in the cavities.

Special measurements were performed to improve the understanding of the seriousness and origin of the defects found. Among them were profilometric measurements, performed on discs 134, 135, 144, 148, 149 and 150, which revealed that the pits are up to 0.5 mm wide and up to 85 microns deep. Smaller pits (<100 microns wide) could not be revealed with the eddy current scanner, but still appeared under the magnifying glass. This is consistent with the 100 micron detection limit of the scanner (note that the scanner is optimized for sub-surface detection).

If one takes into account the results of the special measurements one comes to the conclusion that most of the discs should be available for cavity fabrication. With the issue of roller marks being less well explored we suggest that those be kept away from the inside surfaces of the cavities. We also suggest that the disc-sides with scratches and pits, which do not appear as signal in the eddy current scanner are the preferred ones for the cavity inner surfaces since this usually means that the defects are smaller in size.

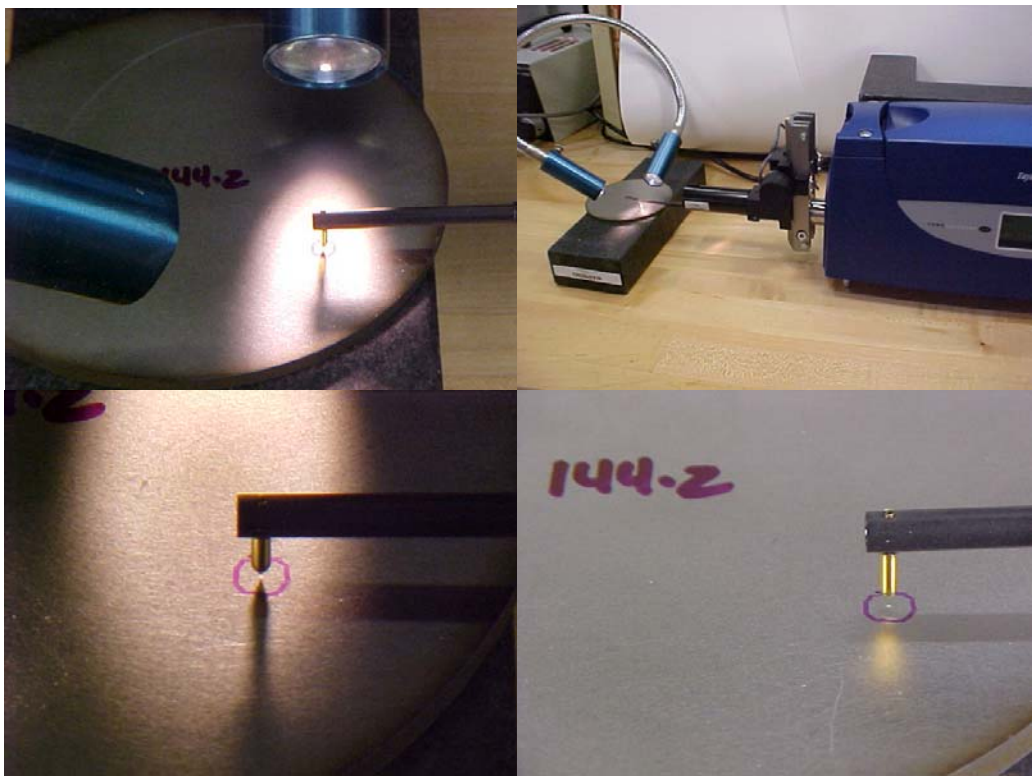
APPENDIX 1

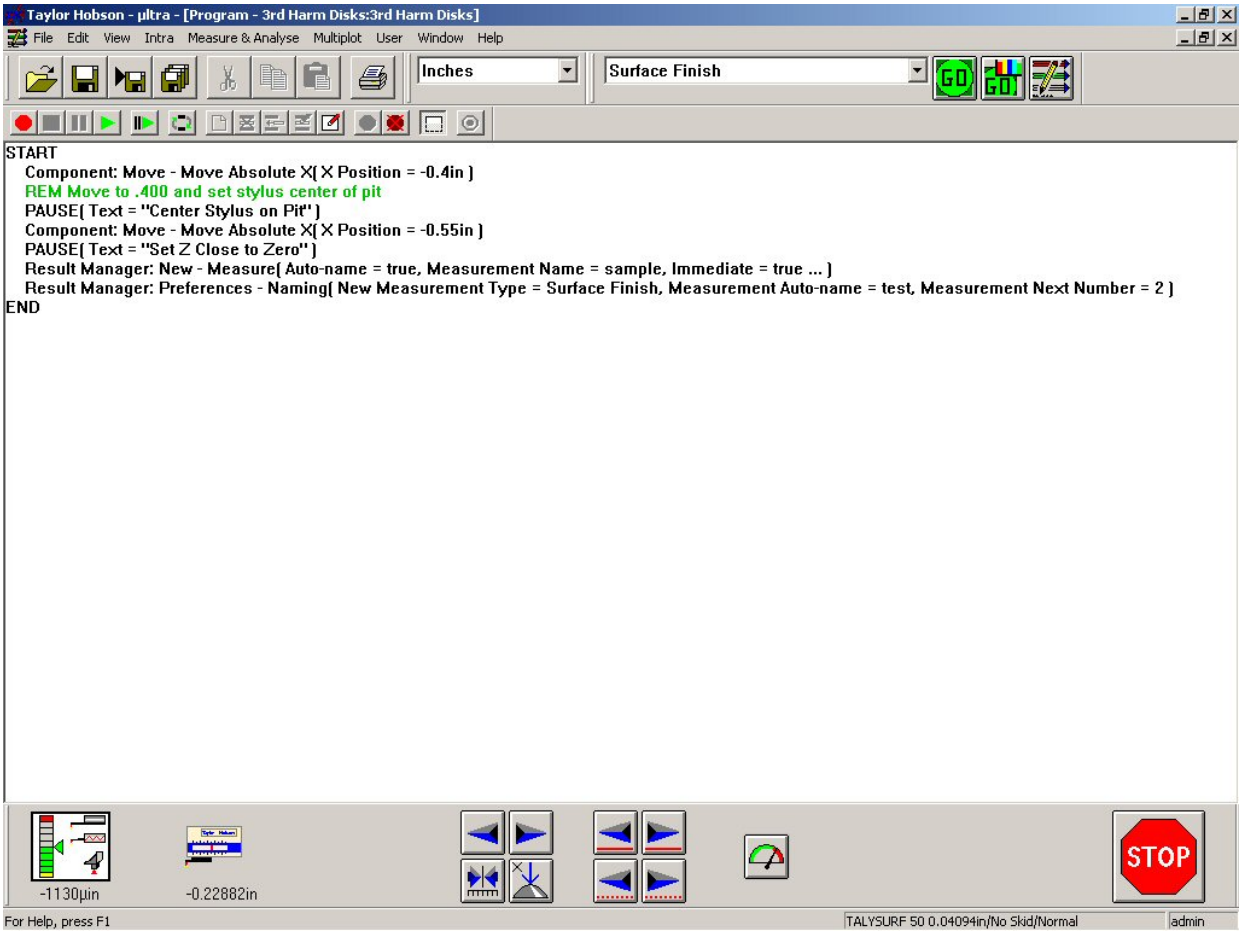
FERMILAB Technical Division
QUALITY CONTROL REPORT

Taylor Hobson Profilometer Pit Measurements Of Discs 134-150 3RD Harmonic Batch 1

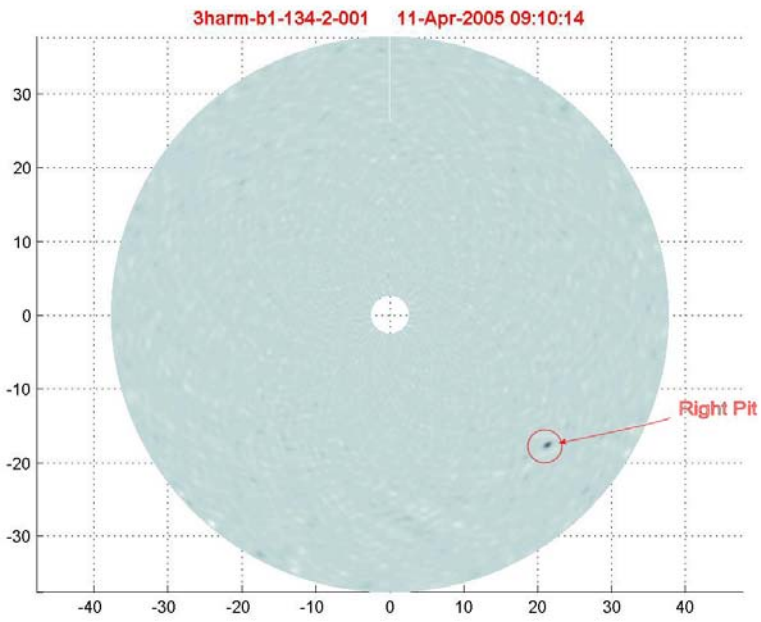
Oscar Lira, May 31, 2005

Several raw pit profile measurements were taken with a Taylor Hobson Talysurf Intra Profilometer with a diamond chisel edge stylus arm of 78.7402µin (=2µm) radius, having two linear axis "X" (stylus traverse) and "Z" (stylus contact to surface). The apparatus is shown below.

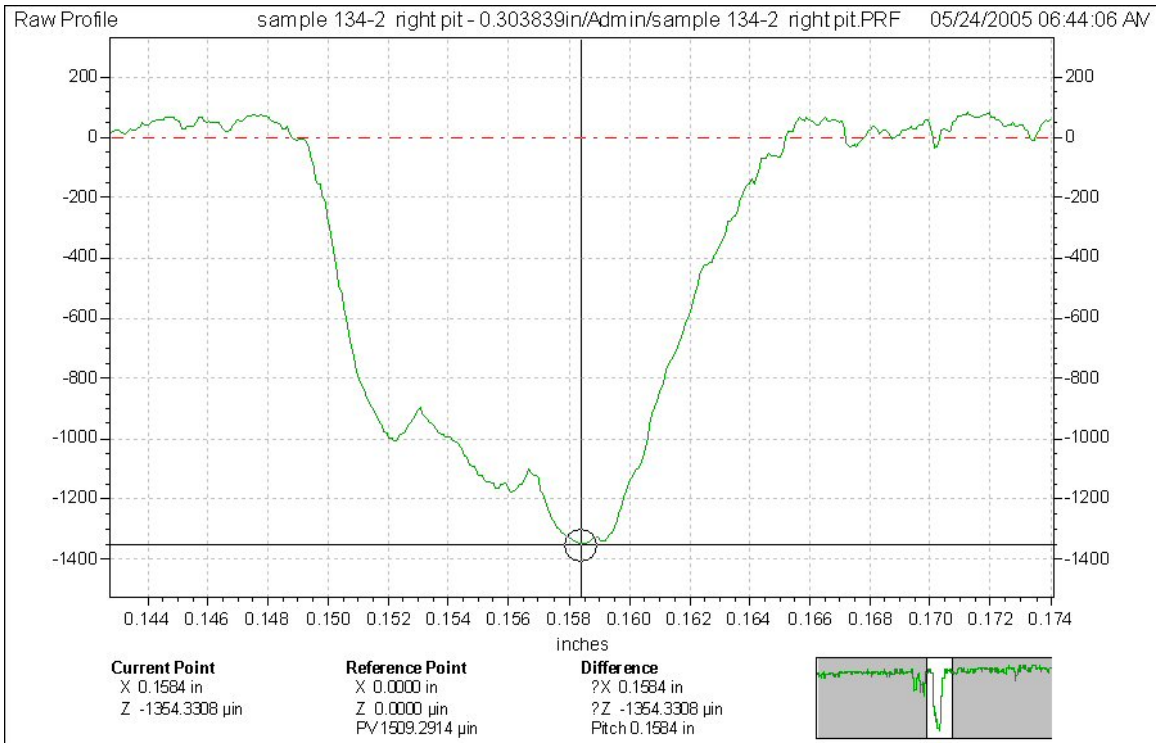




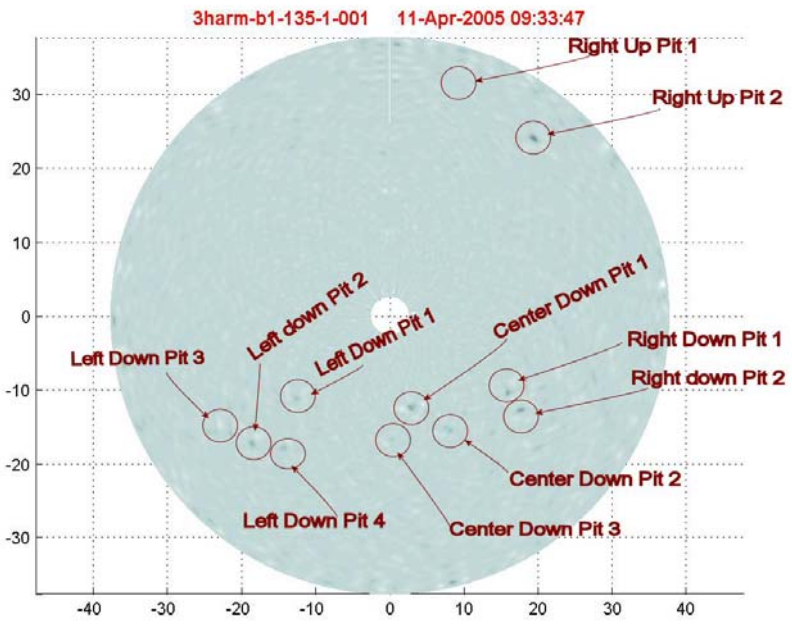
Program used for the measurements, X -.40 (Center of Pit) X-.55 (Start of Measurement) .300 Total length of Measurement.



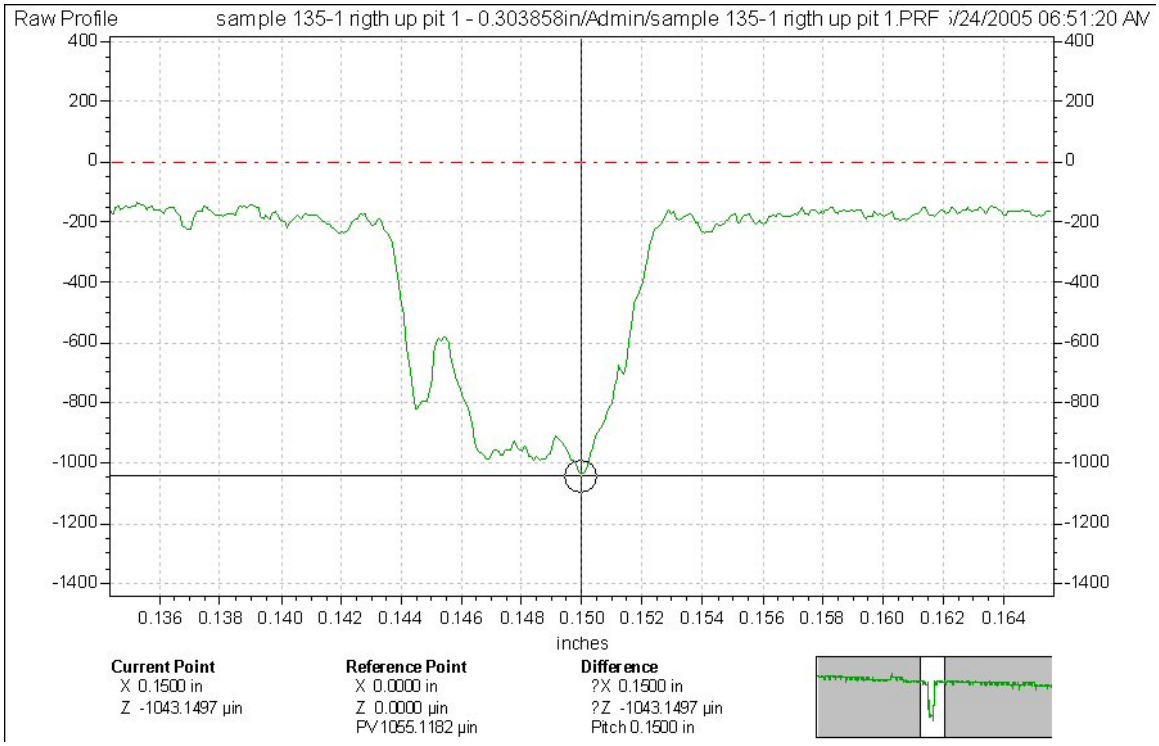
Pit location



Bottom Scale = Inches, Side Scales = µinch



Pit locations



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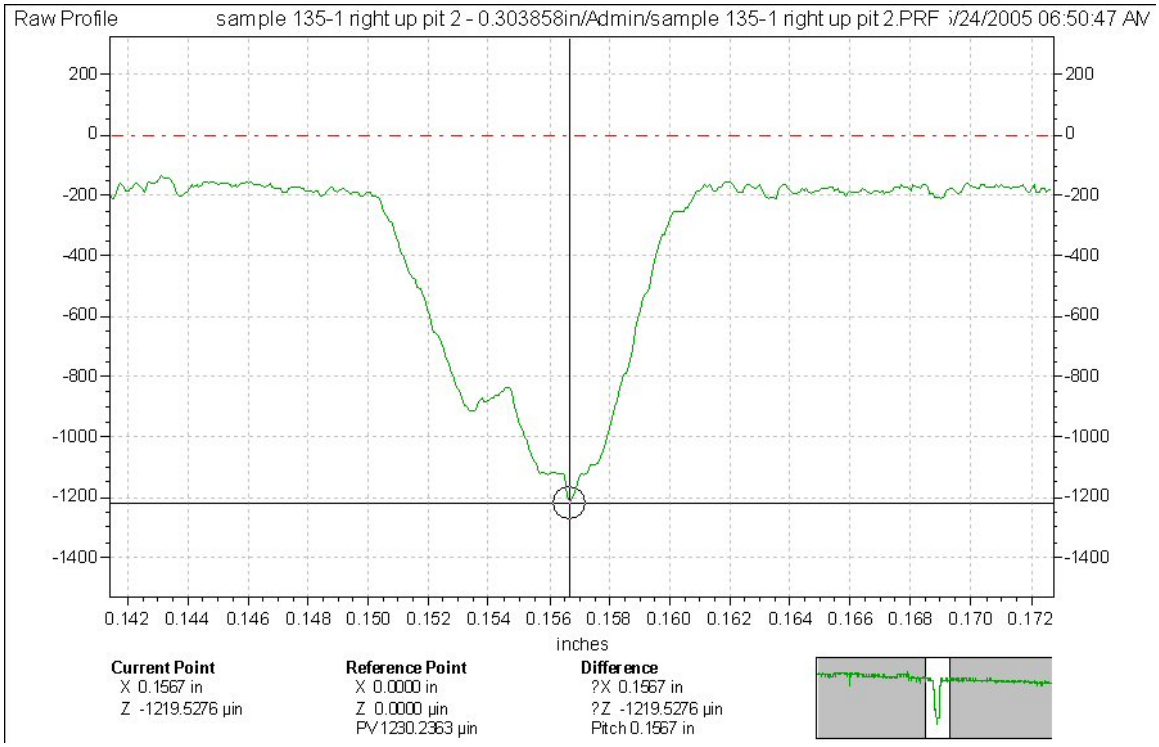

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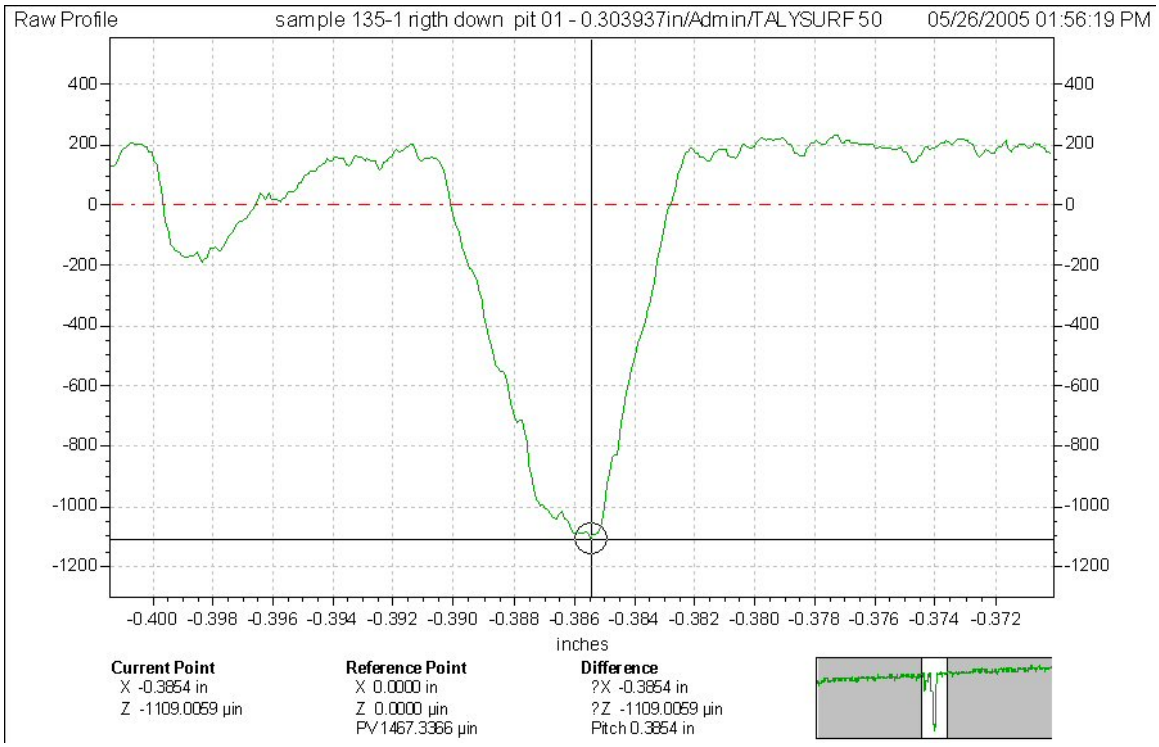

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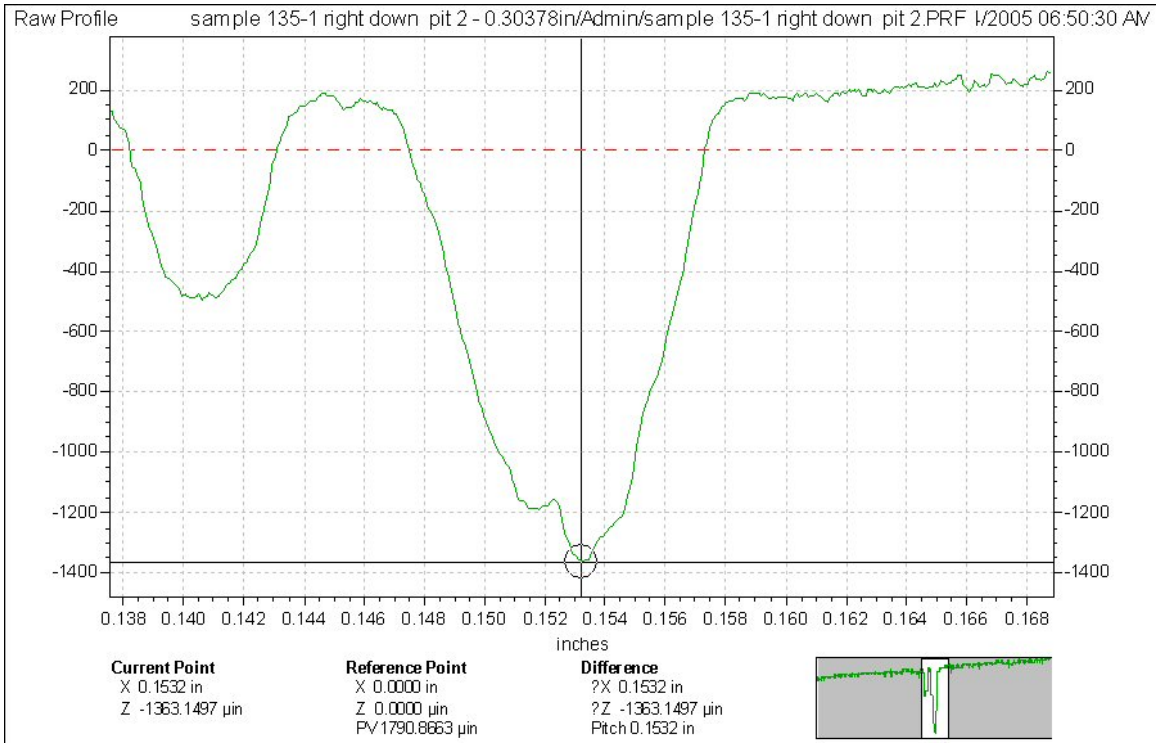

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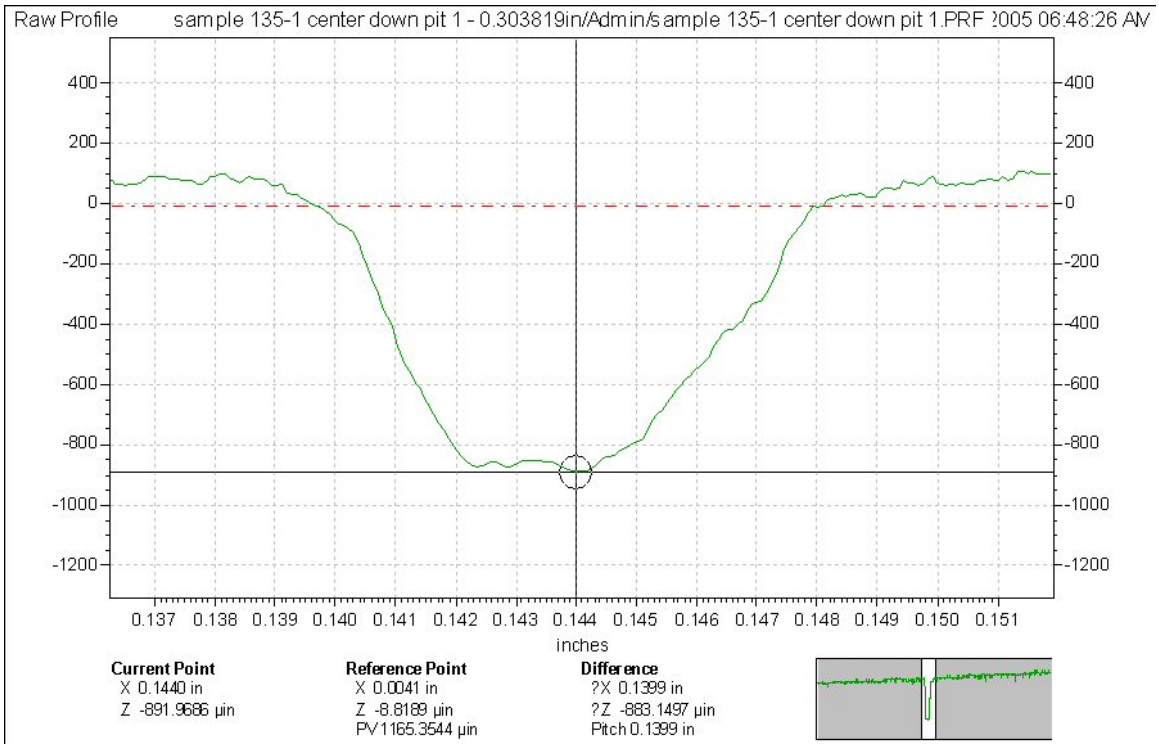

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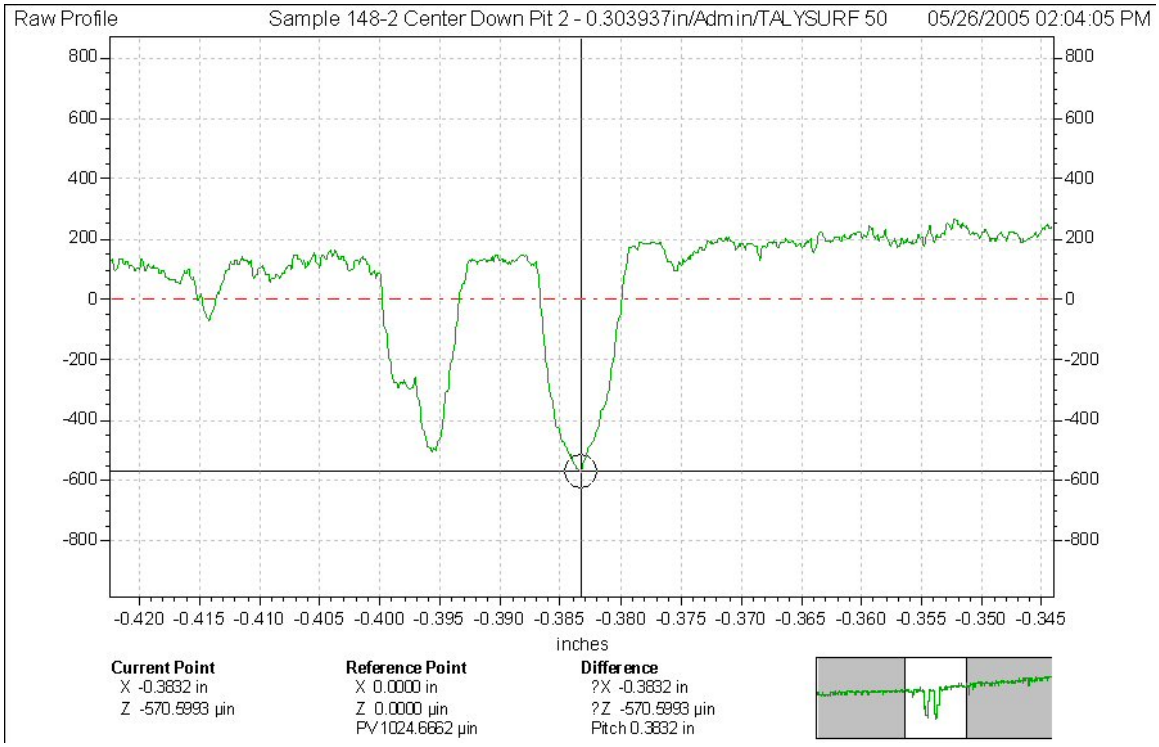

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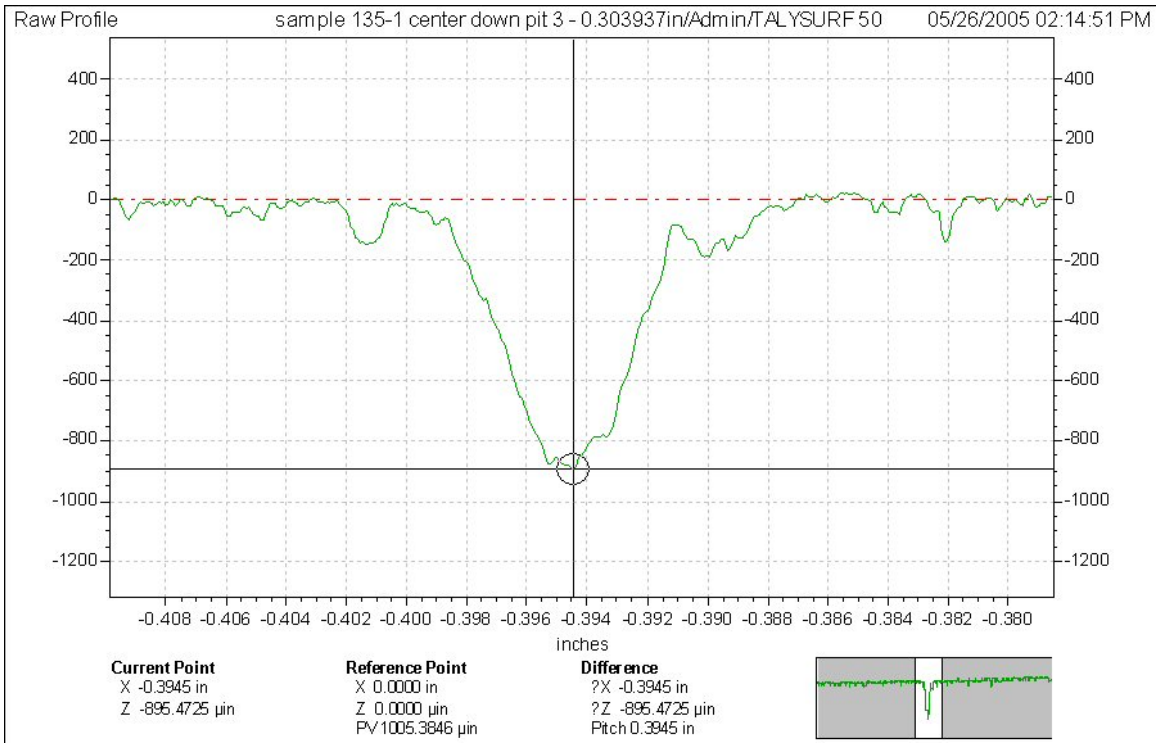

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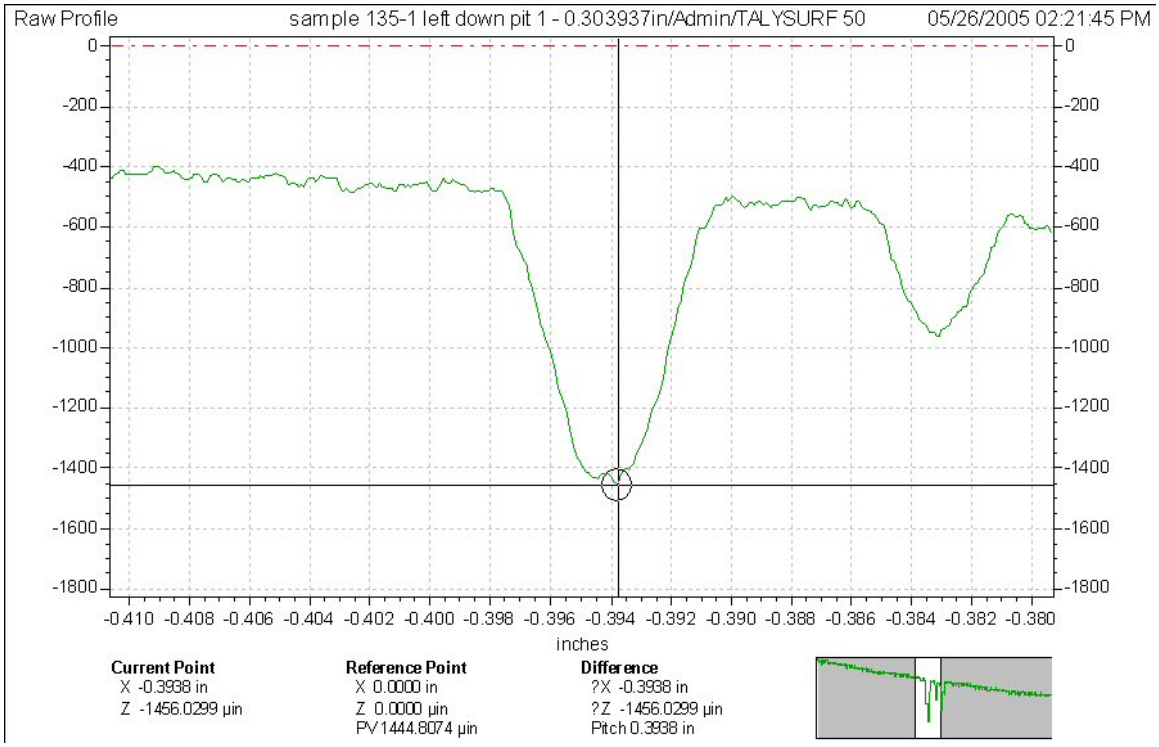

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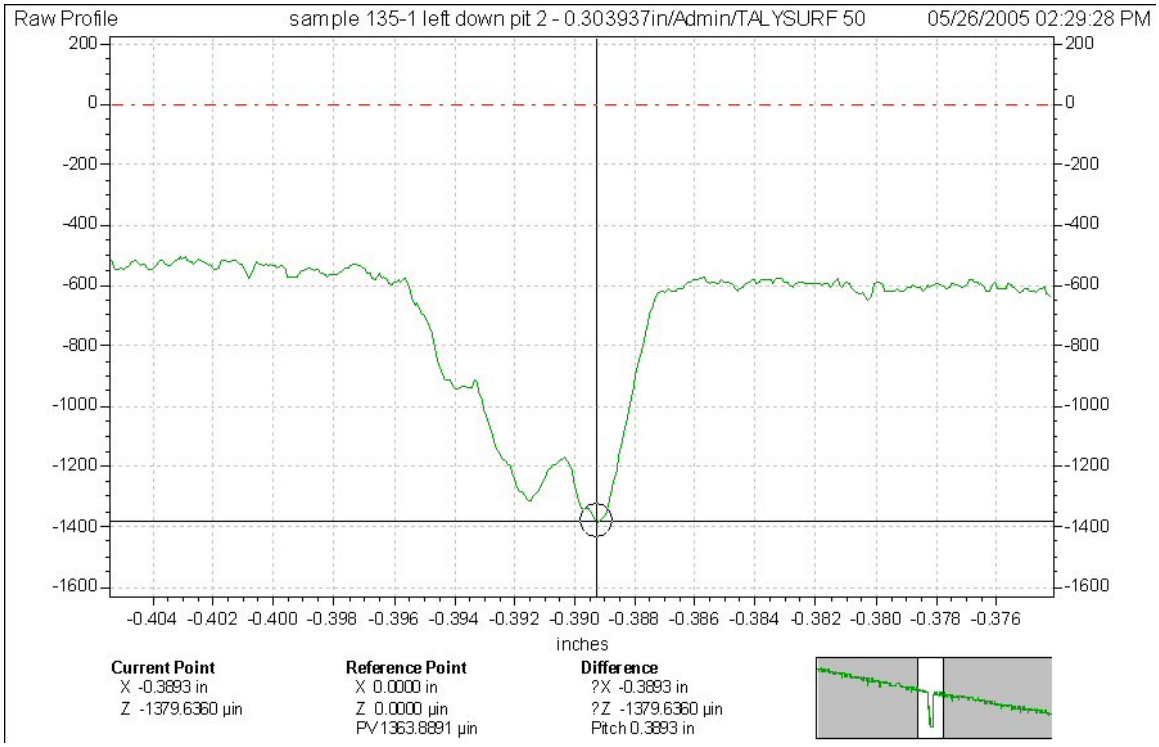

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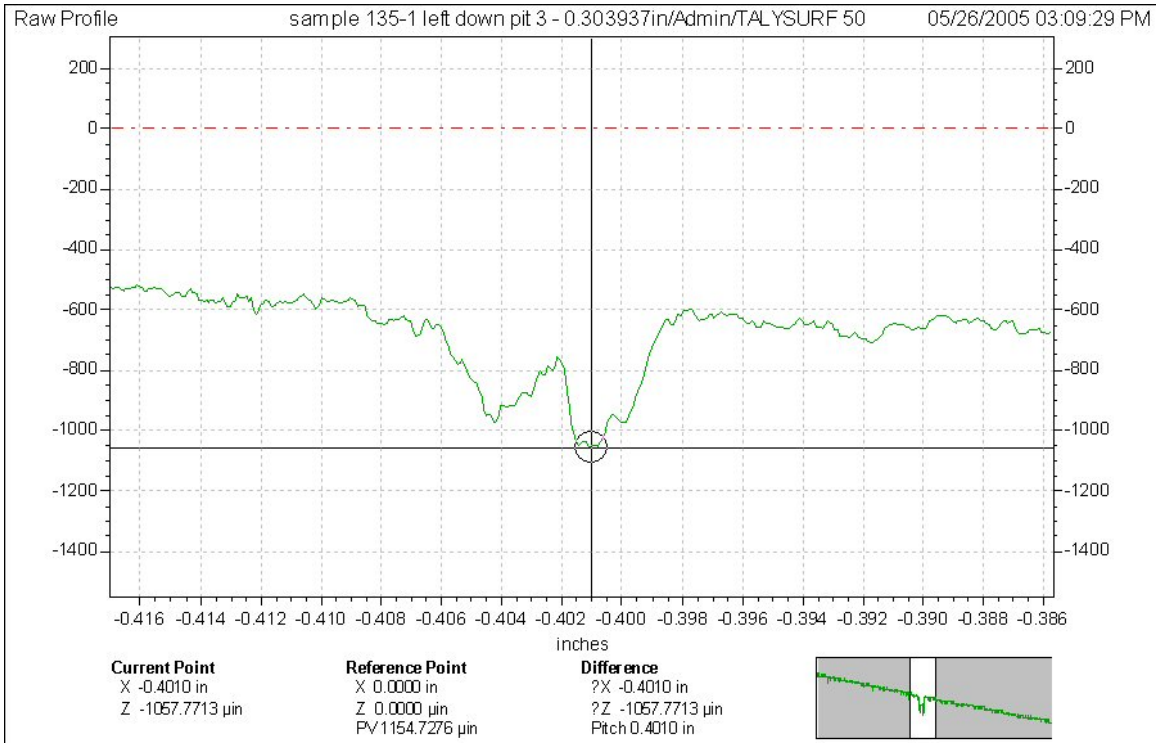

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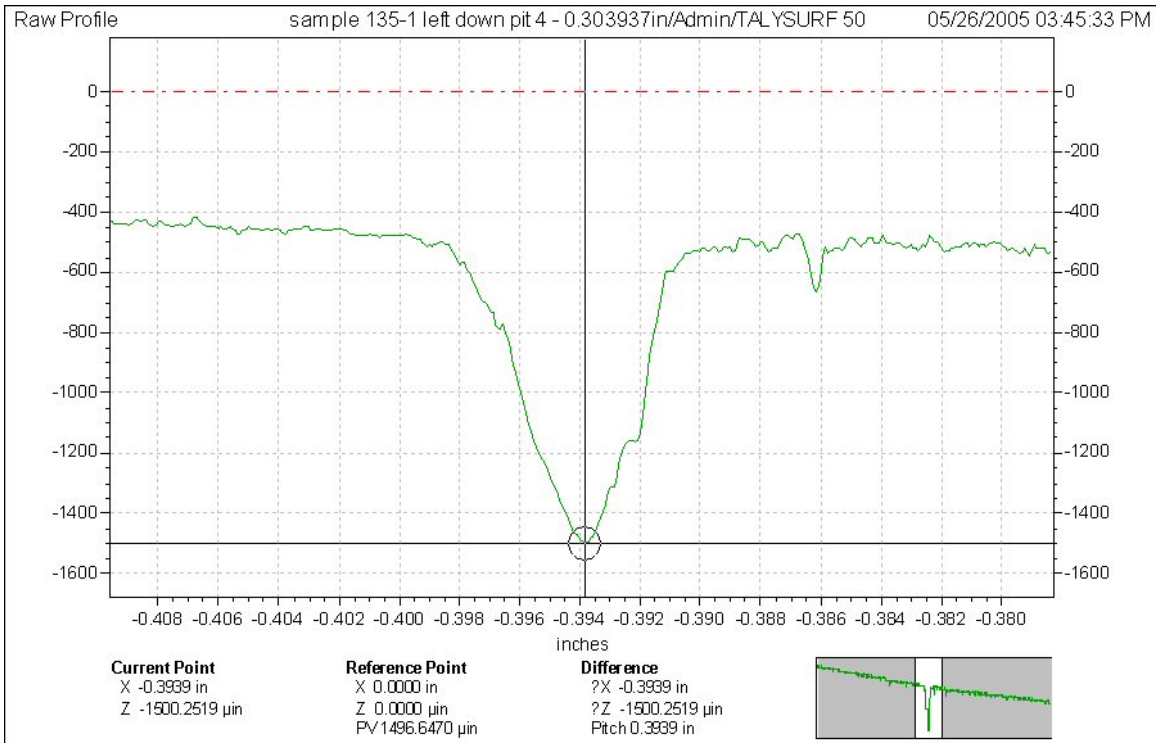

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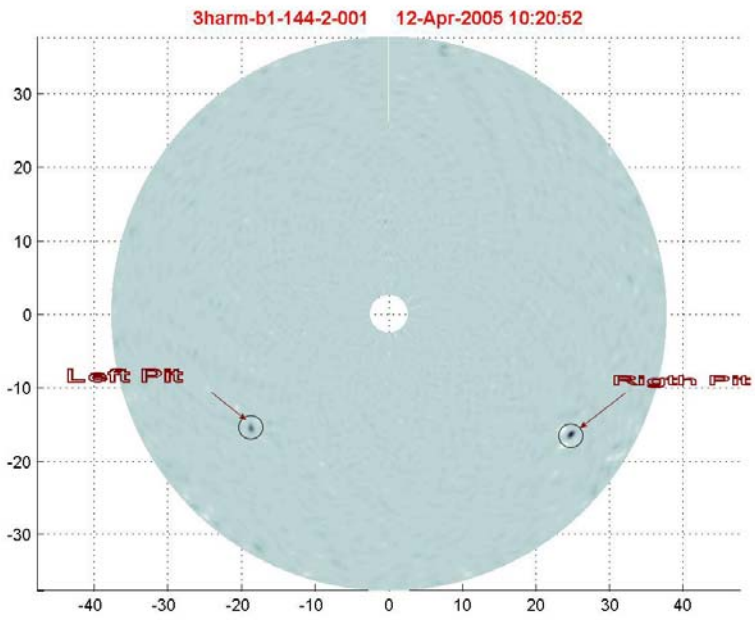
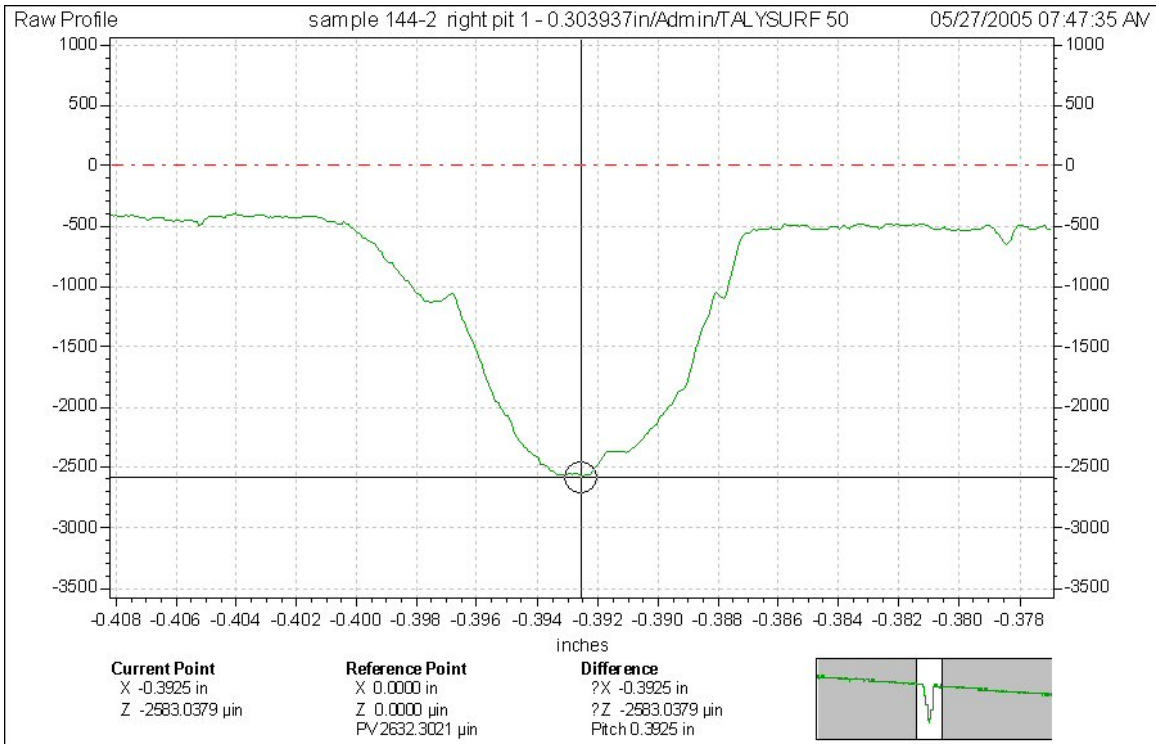


Pit Locations



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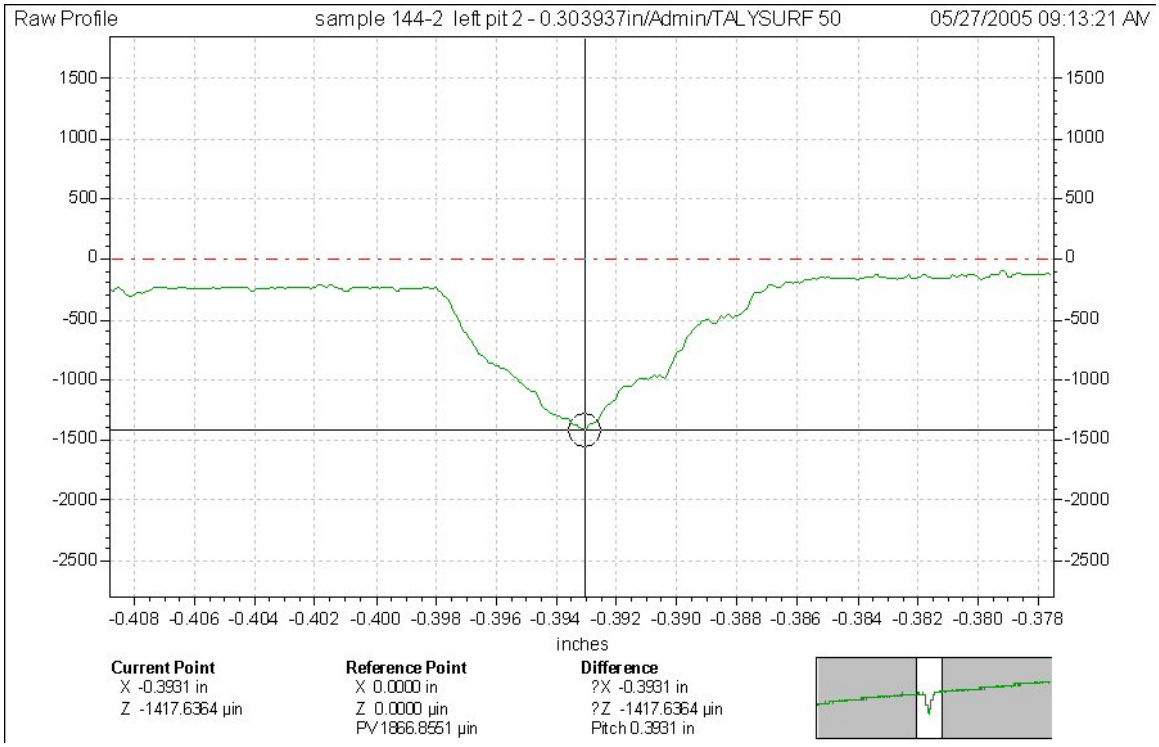

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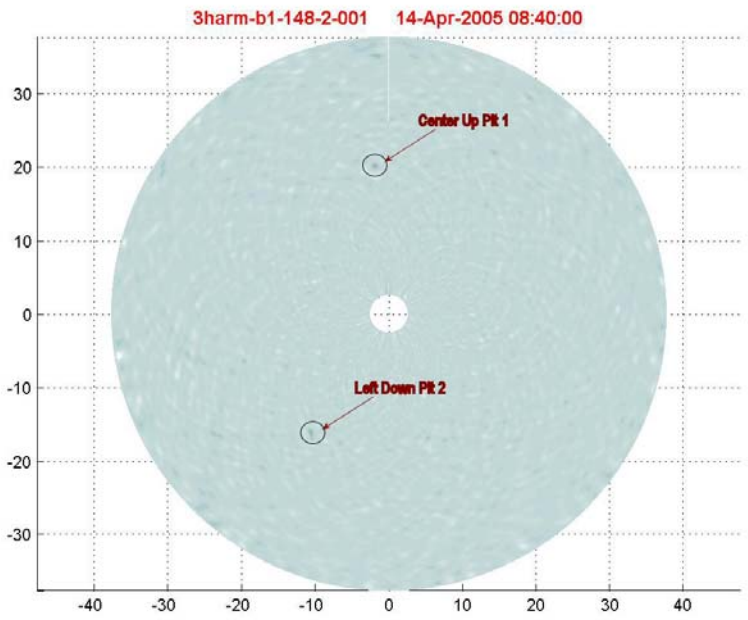

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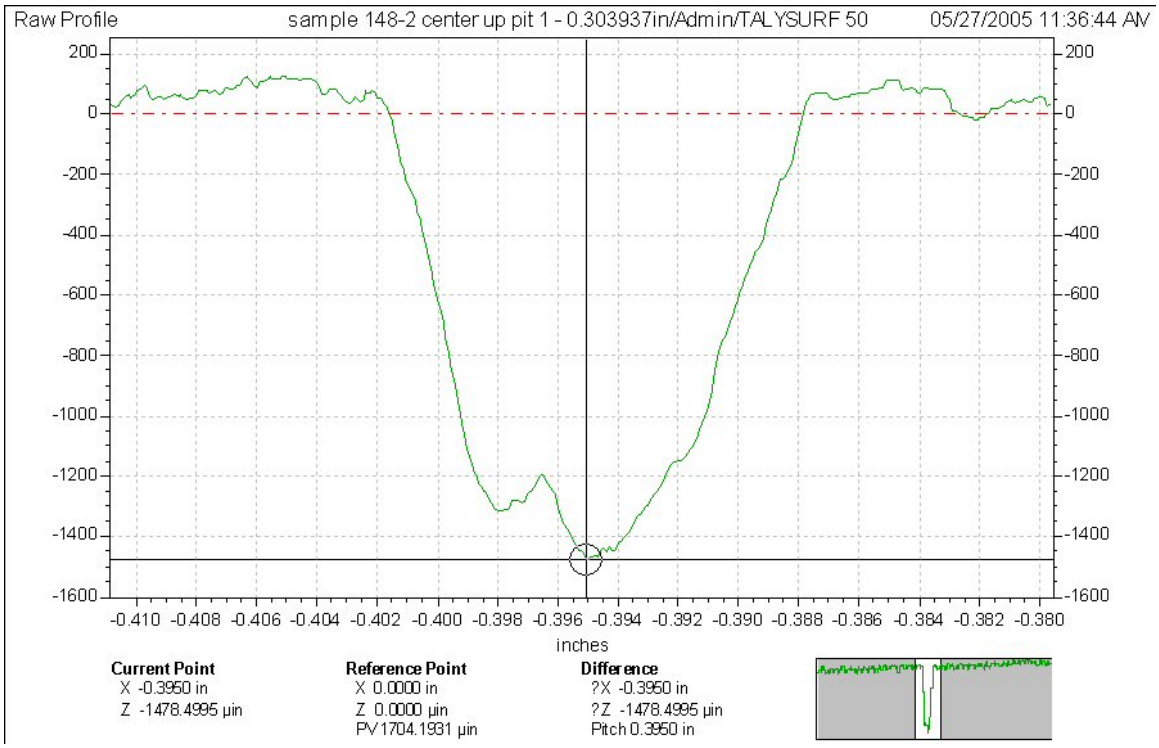

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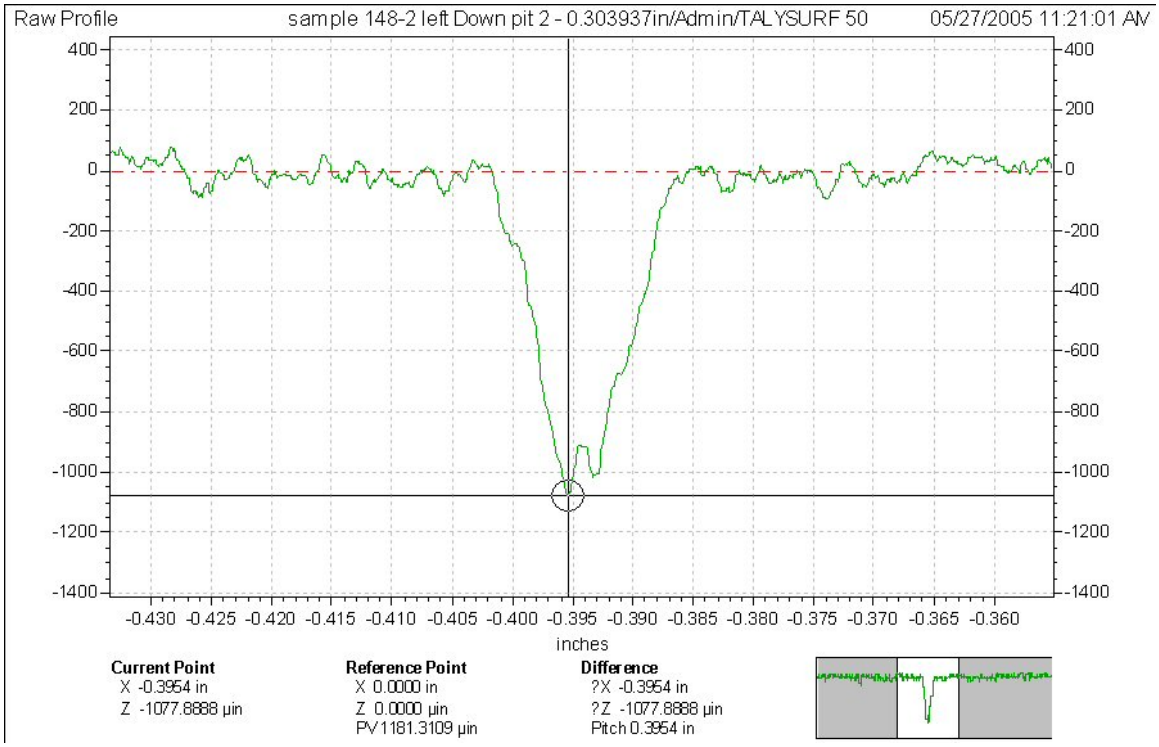

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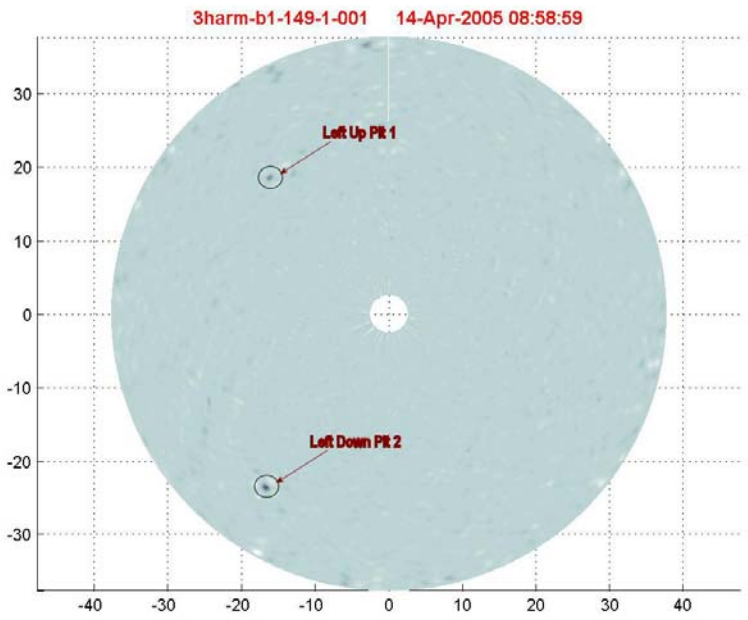

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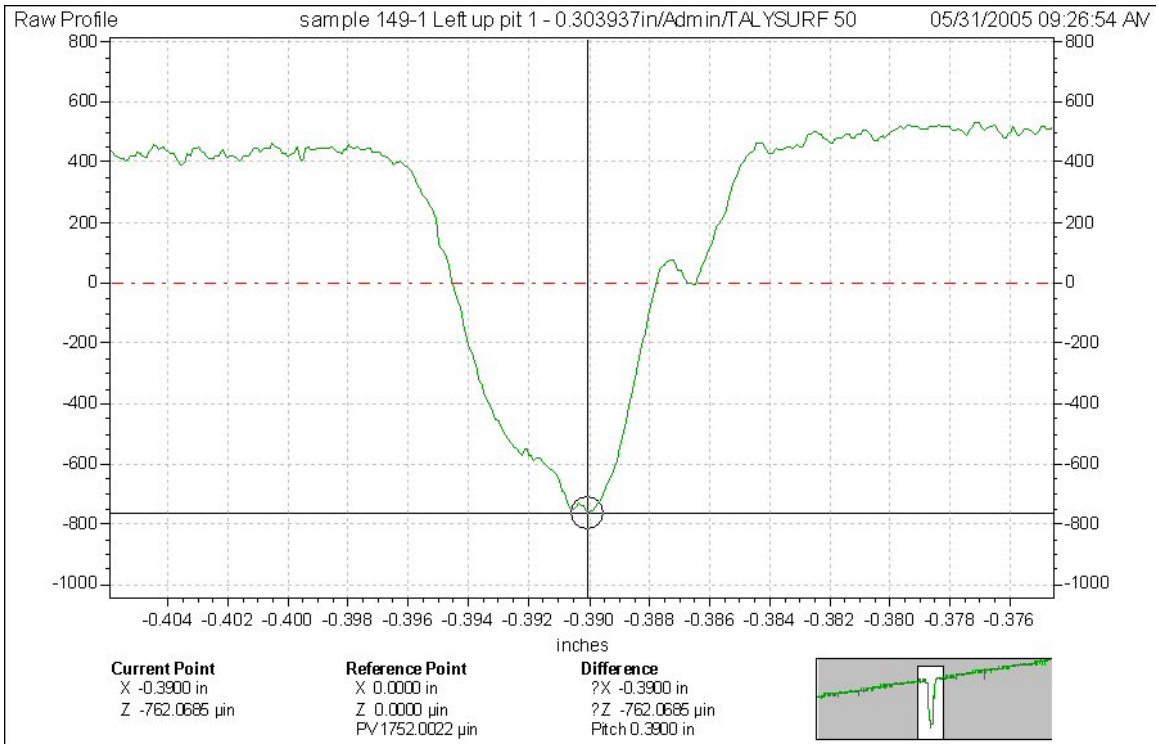

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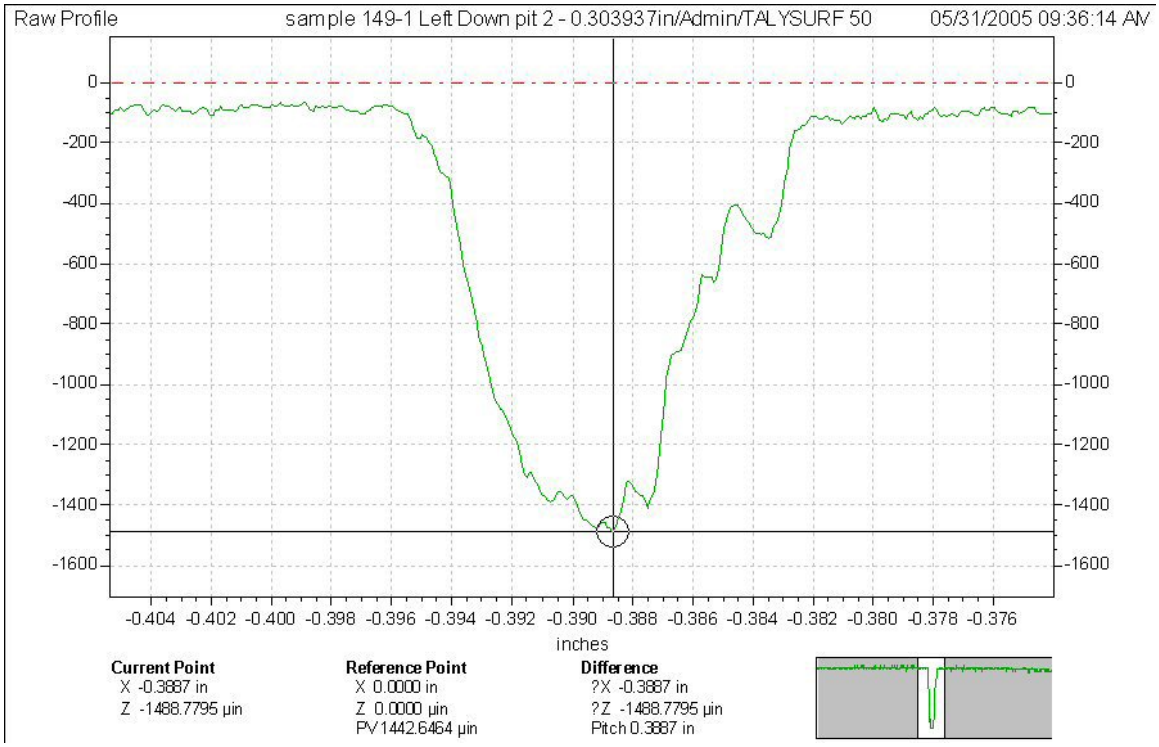

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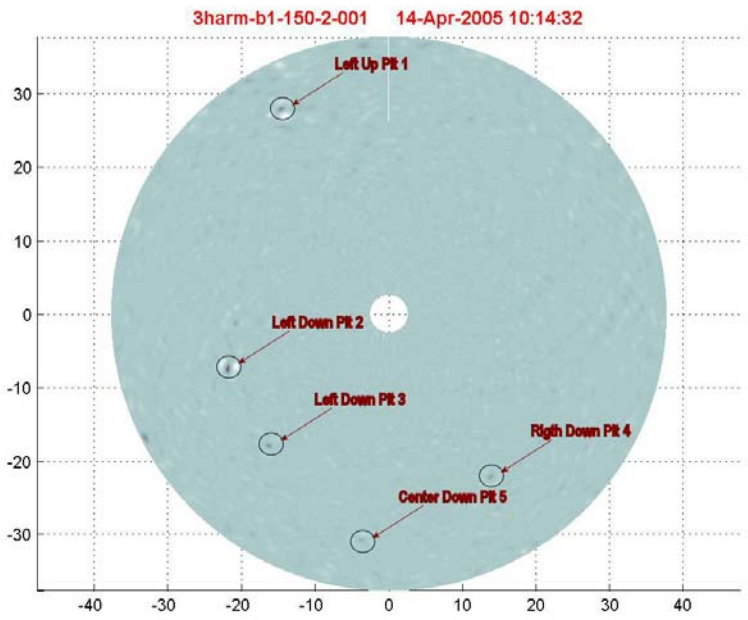
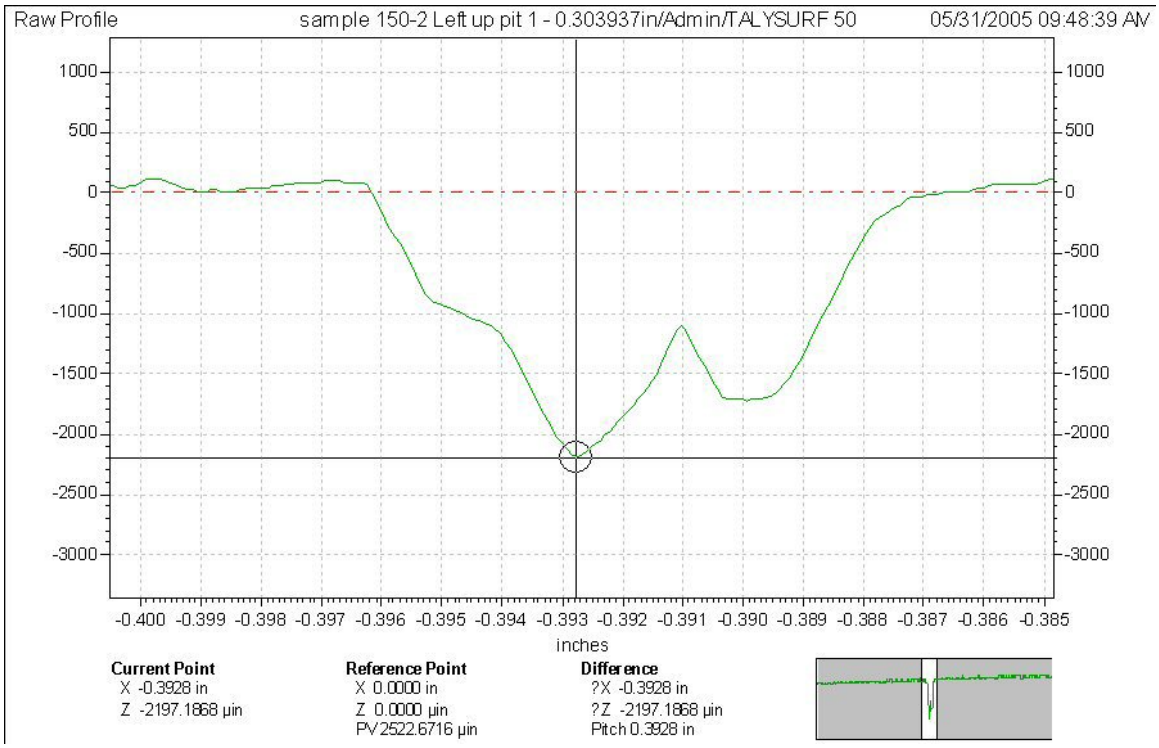


Pit Locations



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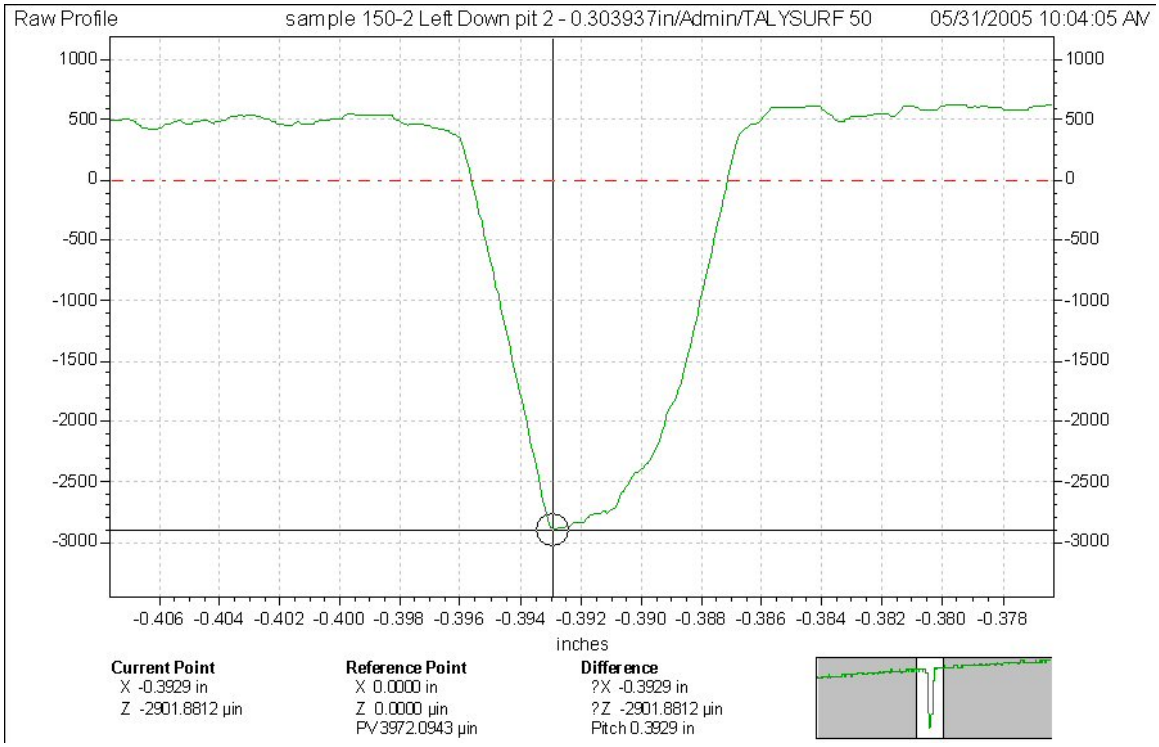

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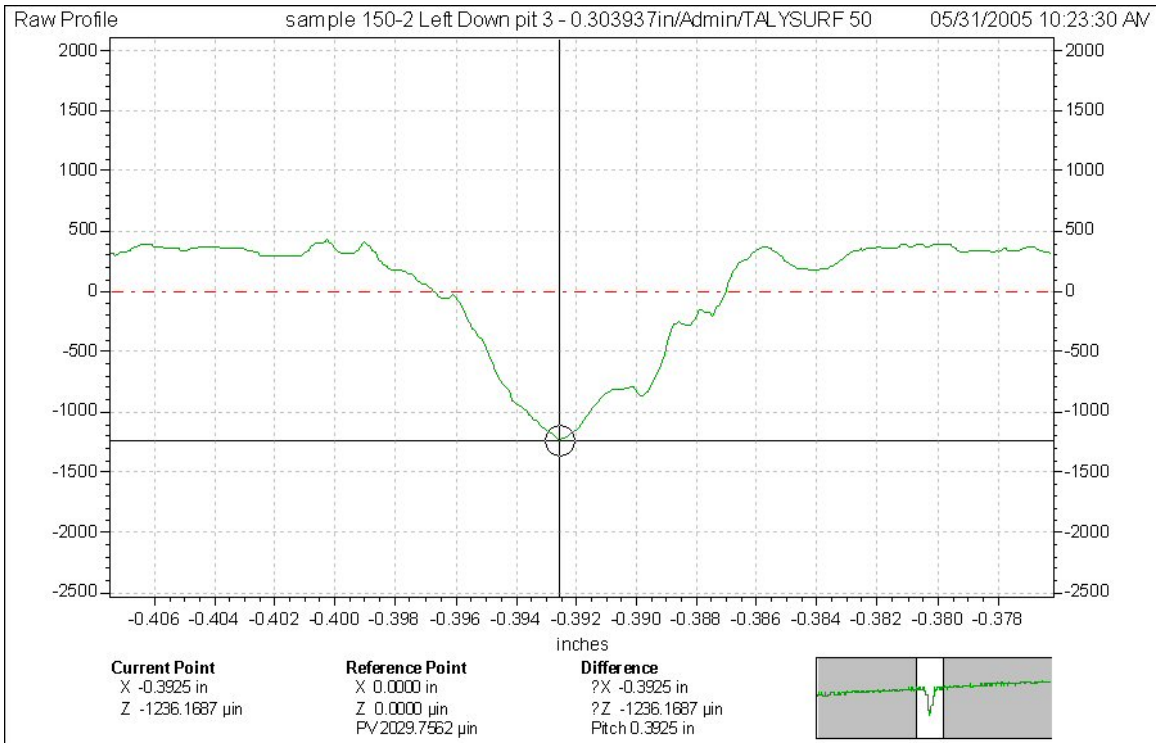

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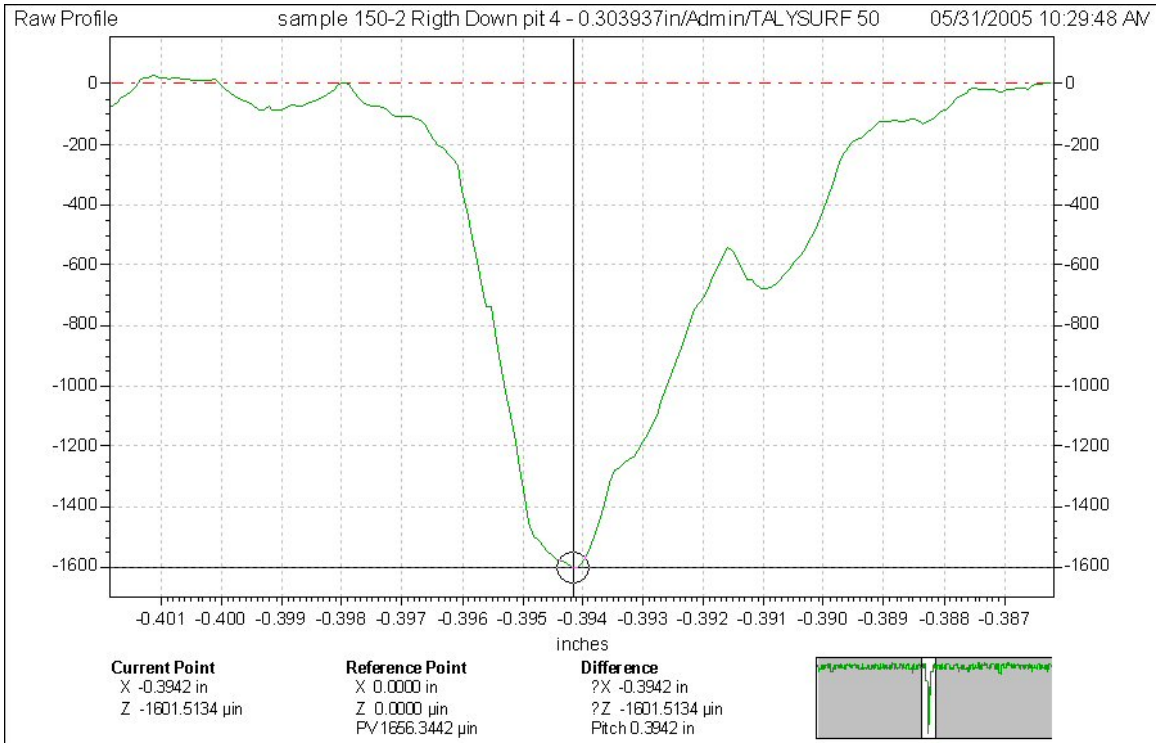

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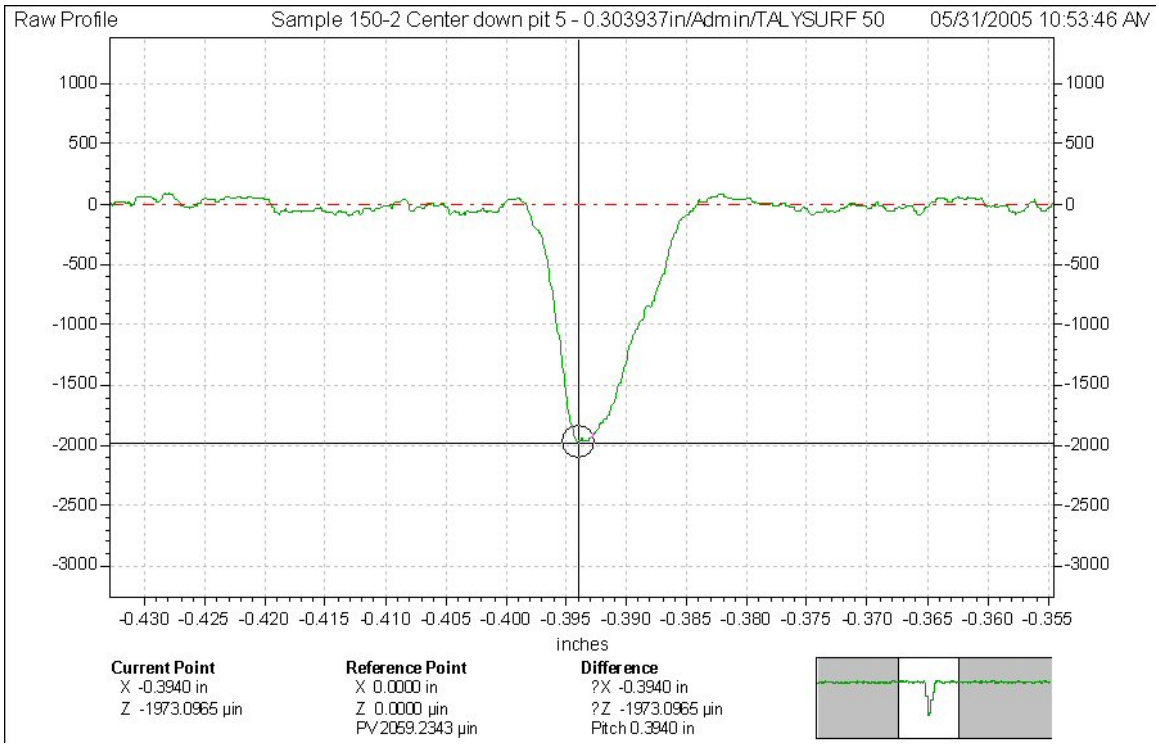

Bottom Scale = Inches, Side Scales = µinch

#	disc	#	depth (μm)	width (mm)
1	134/2	1	34.4	0.46
2	135/1	1	21.4	0.25
3	135/1	2	25.9	0.28
4	135/1	3	33.2	0.23
5	135/1	4	39.7	0.33
6	135/1	5	25.2	0.28
7	135/1	6	19.5	0.25
8	135/1	7	22.7	0.36
9	135/1	8	24.3	0.20
10	135/1	9	19.8	0.25
11	135/1	10	11.6	0.31
12	135/1	11	25.4	0.25
13	144/2	1	52.9	0.36
14	144/2	2	30.9	0.31
15	148/2	1	37.6	0.46
16	148/2	2	27.4	0.46
17	149/1	1	32.1	0.43
18	149/1	2	35.3	0.36
19	150/2	1	55.8	0.25
20	150/2	2	86.4	0.33
21	150/2	3	33.9	0.36
22	150/2	4	40.7	0.28
23	150/2	5	50.8	0.34